



**AN EVALUATION OF A NETWORKED RADIATION DETECTION SYSTEM**

**THESIS**

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AFIT/GWM/ENP/10-M02

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THESIS

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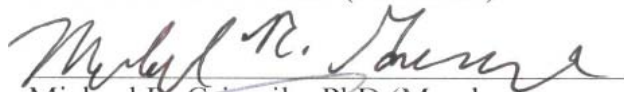
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## **Abstract**

First responders assess a Nuclear/Radiological (NUCRAD) event in a timely and accurate manner by creating a site characterization that reflects the location of various levels of contamination based on their instruments' readings. The survey team experiences difficulty in accurately recording this critical data due to the challenge of operating multiple devices and communicating the devices' readings to other survey members. First responders produce a representation of the contamination or activity on a map that contain rings outlining the levels of activity and/or single locations of a single activity. Recently, several agencies began creating software programs that record a first responder's instrument readings, time, and the global positioning system (GPS) location plotting the information in real-time. The Environmental Protection Agency (EPA) Region 5 developed the Rapid Assessment Tool (RAT). This research evaluates the effectiveness of RAT by comparing the timeliness and accuracy of the site characterization created by multiple survey teams (one team not using RAT and another team using RAT).

All of the Bioenvironmental Engineer (BEE) Survey Teams using RAT decreased their survey times for all scenarios. The Weapons of Mass Destruction – Civil Support Team (WMD-CST) survey teams using RAT decreased their survey times during the lane, bounce and bypass, star, and cloverleaf scenarios. However, survey times increased for the zigzag and radial scenarios.

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MAJ Leif A. Hansen

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## **List of Abbreviations**

<b><u>Abbreviation</u></b>	<b><u>Description</u></b>
AFRAT	Air Force Radiation Assessment Team
ALARA	As Low As Reasonably Achievable
AMDS/SGPB	Aerospace Medicine Squadron/ Bioenvironmental Engineering Flight
AUM	Abandoned Uranium Mines
$\beta$	Beta
BEE	Bioenvironmental Engineer
BNC	Berkeley Nucleonics Corporation®
C2	Command and Control
CBRN	Chemical, Biological, Radiological, and Nuclear
CCP	Concept Capability Plan
CF	Coalition Forces
CM	Consequence Management
COP	Common Operating Picture
CWMD	Combating Weapons of Mass Destruction
DA	Department of the Army
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
FARP	Forward Arming and Refueling Point

FEMA	Federal Emergency Management Agency
FM	Frequency Modulation
FRMAC	Federal Radiological Monitoring and Assessment Center
FWHM	Full Width at Half Maximum
GAO	Government Accountability Office
GDS	Government Decontamination Service
GIG	Global Information Grid
GPS	Global Positioning System
H <sub>2</sub> S	Hydrogen Sulfide
HCN	Hydrogen Cyanide
IC	Incident Commander
ICS	Incident Command System
IND	Improvised Nuclear Device
JFC	Joint Force Commander
JIIM	Joint, Interagency, Intergovernmental, and Multinational
JOA	Joint Operating Area
JSLIST	Joint Service Lightweight Integrated Suit Technology
LaBr <sub>3</sub>	Lanthanum Bromide
LEL	Lower Exposure Limit
LLNL	Lawrence Livermore National Laboratory
LN	Local National
MLB	Major League Baseball®



MSR	Main Supply Route
NaI	Sodium Iodide
NARAC	National Nuclear Security Administration Atmospheric Release Advisory Capability
NGO	Nongovernmental Organizations
NUCRAD	Nuclear/Radiological
O <sub>2</sub>	Oxygen
OC	Observer/Controller
OSHA	Occupational Safety and Health Administration
PAPR	Powered Air-Purifying Respirator
PB	Patrol Base
PC	Personal Computer
PDOP	Position Dilution of Precision
PPE	Personal Protective Equipment
QCC	Quadratic Compression Conversion
R	Resolution
RAT	Rapid Assessment Tool
RDD	Radiological Dispersal Device
RES	Radiation Exposure Status
ROE	Rules of Engagement
RS	Recommended Standard
SA	Situational Awareness

SU	Situational Understanding
SCBA	Self Contained Breathing Apparatus
SNM	Special Nuclear Material
SPM	Single Point Monitor
TOC	Tactical Operations Center
TRADOC	Training and Doctrine Command
TSC	Tri-State Chemical®
TTP	Technique, Tactic, or Procedure
UK	United Kingdom
US	United States
USAF	United States Air Force
USB	Universal Serial Bus
USGS	United States Geologic Survey
VOCs	Volatile Organic Compounds
WMD-CST	Weapons of Mass Destruction – Civil Support Team
XRF	X-Ray fluorescence

# AN EVALUATION OF A NETWORKED RADIATION DETECTION SYSTEM

## 1. Introduction

### 1.1 Background

The Federal Emergency Management Agency's (FEMA) Incident Command System (ICS) depends on first responders assessing a NUCRAD event in a timely and accurate manner. First responders assess the environment by creating a site characterization that reflects the location of various levels of contamination from their instruments' readings. Ultimately, first responders will produce a representation of the contamination or activity on a map. This map will contain isodose lines that delineate levels of activity and/or single locations of a single activity. Currently, among the first responder community, each jurisdiction and agency track their readings with their own system. Most often, first responders who enter the hot zone will transmit their readings, location, and time over frequency modulation (FM) radio to their Tactical Operations Center (TOC). From there, the TOC compiles its data on a digital map and forwards it to its higher echelons and laterally to other agencies across the response. Otherwise, the survey members manually record the information and disseminate it to the TOC upon leaving the hot zone. A key to the products produced by the survey teams is the interoperability. The products must be in a format such that all agencies involved in the response may receive, view, and edit.

## **1.2 Problem Statement**

This research will attempt to evaluate a networked radiation detection system. Specifically, the experiment will show the effectiveness of such a system by comparing the timeliness and accuracy of the site characterization created by multiple survey teams.

Collecting the data in the hot zone requires a considerable amount of time and effort. During the response, the survey team dresses in heavy and physically exhausting Personal Protective Equipment (PPE). This limits the length of time the team operates in the hot zone. Therefore in a large scale response, PPE greatly restricts the ability of a team to complete its site characterization in one entry. Communicating on a radio requires the survey member to consume additional air from their Self Contained Breathing Apparatus (SCBA) tank which further increases the challenge. During the first experiment, survey members wore the Joint Service Lightweight Integrated Suit Technology (JSLIST) and Powered Air-Purifying Respirator (PAPR). During the second experiment, survey members wore Level B PPE. Level B consists of SCBA, chemical-splash suit, inner and outer chemical resistant gloves, and chemical resistant boots.



**Figure 1: WMD-CST PPE**



**Figure 2: BEE PPE**

Another issue of concern relates to the total dose equivalent received by the survey members. The longer survey members spend in the hot zone, the greater the exposure. Therefore, survey members potentially receive a higher dose equivalent. As a result, leaders must keep their survey members' dose equivalents as low as reasonably achievable (ALARA). As a matter of reference, Tables A1, A2, and A3 (Appendix A) display the annual occupational dose equivalents, the potential exposure limits for military survey members, and radiation effects on personnel. Viewing these tables provides the practitioner with a better understanding of the importance of limiting the amount of exposure.

There is a need to develop a technique, tactic, or procedure (TTP) that will limit the amount of time that a first responder spends in the hot zone and therefore decreases their total dose equivalent. There is also a need for the Incident Commander (IC) to receive an accurate Common Operating Picture (COP) within the shortest amount of time in order to ensure maximum protection of lives and safety to the community's citizens.

Accuracy and efficiency represent two significant issues that apply to any chemical, biological, radiological, and nuclear (CBRN) response.

### **1.3 Research Objectives**

Currently, RAT integrates with only Ludlum®, models 2221, 2241, 2350-1, and the Fluke®, model 451P. Unfortunately this list doesn't include the Air Force's primary detector used by first responders, the Canberra® ADM300. The objectives of this research include:

1. Convert the data from the ADM300 in order to integrate with the RAT software.
2. Conduct an experiment whereby we are able to analyze the performance of the system.
3. Analyze the collected data from the experiment.
4. Identify gaps and challenges with the system.

As a result of this research, the following three recommendations may develop:

1. Recommend the system for the BEE community and potentially the Air Force Radiation Assessment Team (AFRAT).
2. Recommend improvements to the existing system.
3. Provide the EPA with the data conversion code for the ADM300 and RAT system.

### **1.4 Focus of Evaluation**

(1) The system will be user friendly and thus represent a relatively simple tool to teach untrained reinforcements arriving at a response.

(2) The system will be efficient by demonstrating great accuracy with a reduced survey time.

(3) The system will be durable.

## 2. Literature Review

### 2.1 RAT applications to Consequence Management (CM)

A 14 September 2009 United States (US) Government Accountability Office (GAO) report by Gene Aloise, Director Natural Resources and Environment, criticizes the US's ability to recover from NUCRAD attacks. According to a National Science and Technology Council report referenced by Aloise, "the ability of government to quickly and decisively respond to and recover from a radiological dispersal device (RDD) or improvised nuclear device (IND) incident is key to national resiliency." (Aloise, 2009) The council understands the importance of restoring government services back to a functional level. Furthermore, the council continues that a quick cleanup and recovery may deter a subsequent attack due to the enemy's perception that he is unable to project long-term suffering and disruption to the US (Aloise, 2009). Aloise states that "...quickly analyzing and cleaning up areas after a deliberate release of radioactive materials could speed the recovery from such an attack by restoring normal operations of critical infrastructure, services, businesses, and public activities, and thus reducing the many adverse consequences from an attack." (Aloise, 2009) In other words, the responders must first assess the situation and gain a good understanding of the scope of the problem. Failure to gain a timely site characterization will escalate and prolong the adverse consequences of an attack.

A recent Department of Energy (DOE) planned exercise in Albany, NY involving local, state, and federal response agencies brought to light the issues and challenges



associated with the handover of the Federal Radiological Monitoring and Assessment Center (FRMAC) from the DOE to the EPA (Aloise, 2009). Specifically, the agencies felt concerned regarding "...the level and quality of the monitoring data necessary for EPA to accept the leadership of FRMAC." (Aloise, 2009) RAT's current capabilities and ability to integrate additional detectors represent a potential solution to this challenge.

Not only does obtaining a timely site characterization limit the adverse intentions of the attack, it also creates significant savings in resources such as personnel and equipment. According to Lawrence Livermore National Laboratory (LLNL) decontamination experts, an increased delay in executing remediation actions "dramatically" increases decontamination costs (Aloise, 2009). Aloise's report determined that the inadequate federal resources will prevent the completion of the site characterization and other critical tasks in a timely and effective manner (Aloise, 2009). As a result, during a federal response to a RDD or IND event, the IC may require responders, who don't normally operate detectors, to conduct a significant portion of the site characterization. Therefore, trainers must quickly teach the site characterization apparatus to these responders. The user friendliness and relatively ease of learning RAT represent significant solutions to the challenge.

Aloise attempts to offer a solution to the current challenges involving an RDD or IND response. Moreover, he mentions the creation of the United Kingdom (UK) Government Decontamination Service (GDS) as a cost savings approach that maintains one federal organization in lieu of multiple similar redundant capabilities at all lower levels of government (Aloise, 2009). Finally, Aloise assesses the UK as somehow better

prepared to respond than the US because of the GDS's response to the 2006 London polonium incident and, "...in particular... UK officials gained an appreciation for the need to have... a process for determining cleanup levels..." (Aloise, 2009) A search of the GDS's web-site provides the following question ("Frequently asked questions," 2009):

"Q6. Will the GDS have a role in monitoring contaminants before and after clean up?"

"A6. The GDS does not have a specific capability to undertake monitoring, sampling or surveying of contaminated sites, though it can advise on organizations (sic) able to provide such capabilities. The Home Office is leading work to determine the monitoring requirements."

This question and answer suggest that the GDS lacks a RAT-like system. Although Aloise claims that GDS offers a solution to the challenge, he fails to mention a specific solution. Perhaps GDS has solutions that it chose to share with Aloise but not revealed on its public web-site.

## **2.2 RAT applications to Department of Defense (DOD)**

US Army Training and Doctrine Command (TRADOC) Pamphlet 525-7-19 provides guidance for combat developers with the task of providing combating weapons of mass destruction (CWMD) capable forces (Vane, 2009). This pamphlet addresses several of the current gaps and challenges within the DOD's CBRN detection.

The pamphlet states that soldiers, with CBRN knowledge, must provide commanders with fully integrated CWMD information in order to produce situational understanding (SU) for the commander's decision cycle (Vane, 2009). The pamphlet

continues that the US Army relies too much on hazard prediction modeling and “...should focus on such things as producing real time hazard awareness.” (Vane, 2009) Specifically, “the Joint Force Commander (JFC) lacks the ability to refine hazard-modeling predictions with actual information in real or near real time to aid in contamination avoidance.” (Vane, 2009) In addition, “the JFC lacks adequate capability to communicate contamination boundaries to multinational forces, civilian populations, nongovernmental organizations (NGOs), and other non-network connected entities.” (Vane, 2009) RAT provides the solution to this challenge of providing real time hazard awareness to the commander, other agencies, governments, civilian populations, NGOs, and other entities.

The needs analysis for the Concept Capability Plan (CCP), discussed in the pamphlet, revealed “...several current CWMD capability shortcomings...” (Vane, 2009) First, CBRN sensors are “...either not networked or poorly networked to the COP.” (Vane, 2009) Second, “tactical and operational units performing CBRN operations do not have an assured, rapid interactive information linkage with pertinent entities up to and including joint, interagency, intergovernmental, and multinational (JIIM) assets.” (Vane, 2009)

One of the ways in which RAT provides a solution for these challenges is through the presence of a quality COP. The pamphlet maintains that the COP must contain the following 11 capabilities (Vane, 2009):

1. The COP must “...provide a comprehensive picture of the CBRN hazard environment.”
2. The COP must “...support automated information flows.”

3. The COP must format, plot, translate, correlate, aggregate, organize, categorize, analyze, evaluate, fuse, and display information.
4. All mission areas must be able to access and share the information.
5. The COP must correlate local national (LN) observations for WMD indicators.
6. The COP must fuse information from various sensors.
7. The COP must "...gather and present the location, sustainment and protection status, and missions of all elements of the force, including joint and coalition partners in order to enable effective command and control (C2)."
8. The COP must display locations and characteristics of hazards.
9. The COP must "...enable tactical echelon access and update."
10. The COP must "...display locations and tracks (if moving) of WMD materials within and transiting the Joint Operating Area (JOA) in order to maintain situational awareness (SA) and SU and enable mission planning."
11. The COP must enable mission planners to conduct CBRN force protection risk assessments.

Currently, RAT achieves seven of these 11 capabilities (1, 2, 3, 4, 6, 8, and 11).

### **2.3 RAT application to EPA**

Over the past five years, the EPA used RAT on multiple occasions. One of the responses occurred in the vicinity of Monument Valley Navajo Tribal Park, UT.

According to Cooper, the following summary describes the remediation efforts conducted at the site using RAT (Cooper, 2008a):

"Beginning in the 1940's, widespread mining and milling of uranium ore for national defense and energy purposes on the Navajo Nation led to a legacy of abandoned uranium mines (AUMs)." The survey site consists of an AUM located at the top of a Sandstone cliff with waste piles located at the base. The survey site is located within 200 yards of the nearest residence and within one mile of the Monument Valley Navajo Tribal Park, UT. Two survey teams, using RAT and a push cart, conducted a site characterization of a one-quarter mile square of rugged and steep terrain. The survey team overcame the difficulties encountered by the waste pile's steep terrain and lack of GPS signal by using a backpack system for the former and a GPS laser for the latter. The survey teams collected 15,000 survey points over the two day operation. Following the survey, the EPA took the data from RAT and created two dimensional and three dimensional contour

visualization products. These products revealed "...that elevated counts are moving down gradient from the waste pile through various outwash channels in a north direction." However, the products reveal a second area to the east that contained elevated measurements. Upon initial inspection of the three dimensional view, it appears that the contamination arrived through washout; however, only upon viewing the two dimensional view do we notice the lack of continuous flow to this eastern location. Furthermore, the survey teams identified cables and wood structures near this eastern location which support the idea that the operators used a gondola to off load the waste at this eastern location.

Furthermore, Cooper summarizes the remediation efforts conducted in and around the home-sites using RAT (Cooper, 2008b):

Additional survey teams surveyed over 50 home sites. Most of the home sites required two RAT survey teams whose rate of march equaled one foot per second. The survey teams executed the surveys using six foot transects, collecting one point per second, measuring between 500 and 5000 survey points per home site, and totaling over 400,000 survey point for the 50 home sites. "The RAT teams after one day of training were able to efficiently survey and troubleshoot hardware and software issues." "The data from these analyses will be used to help prioritize possible clean-up and removal actions per property. The RAT tools provided a valuable method for site characterization and analysis. To be able to rapidly collect huge amounts of data collected for each property, a defensible detailed surface assessment can be achieved."

The EPA conducted air monitoring with RAT for numerous additional real world responses. RAT proved extremely valuable in providing the IC with a COP during the following responses:

1. 2004-2005, navigated with RAT and collected data using RAT and x-ray fluorescence (XRF) for lead contamination at Jacobsville residential neighborhood, Evansville, IN which enabled RAT "...to interpolate and contour the collected data to predict patterns of contamination..." in order to determine future sampling points (Cooper, 2007).
2. 4 May 2005, conducted mobile air monitoring during the removal of 30 bulging and leaking drums at Tri-State Chemical® (TSC), Macon, OH (Cooper, 2006).
3. 9 May 2005, developed a sampling plan from RAT, used RAT to navigate from point to point, used RAT's manual data collection feature, and used RAT

- “...to interpolate and contour the collected data to provide site-wide estimates of emissions...” at Warren (OH) Recycling Inc.®’s 85 acre landfill emitting hydrogen sulfide (H<sub>2</sub>S) (Cooper, 2007).
4. 7 July 2005, conducted air monitoring at an alternative plastics fire in Greendale, IN in order to identify exclusion and safety zones (Cooper, 2007).
  5. 12 July 2005, conducted mounted perimeter monitoring using a RAE® device, Draeger® device, Ludlum® device, GPS receiver, Panasonic® Tough Book, Kowasaki® Mule, mobile wireless network, and RAT at the Major League Baseball® (MLB) All-Star game in Detroit, MI in order to create a single spatially indexed data set (Cooper, 2007).
  6. 19 July 2005, conducted mobile perimeter monitoring at a tire fire at the Watertown, WI Tire and Recycling® facility (Cooper, 2007).
  7. 28 August 2005, conducted air monitoring at a rail car fire releasing styrene near Lunken Airport, Cincinnati, OH and used RAT produced maps to brief ICs and mayors in order to facilitate necessary decisions (Cooper, 2007).
  8. 3 April 2006, conducted site characterization, sampling, and inventory at Northwest Plating® warehouse containing “...30-40 gallon... vats... labeled ‘cleaner,’ ‘rinse,’ ‘acid,’ ‘zinc,’ ‘cadmium,’ ‘copper,’ ‘dip,’ and ‘nickel’... overflowing onto the floor” (Cooper, 2007).
  9. 17 January 2007, conducted air monitoring at an 80 car train derailment in Brooks, KY containing 12 cars carrying cyclohexane, methyl ethyl ketone, and aniline (Cooper, 2007).
  10. Used RAT to navigate to the radial sample design and parcel data coordinates, took XRF readings of Arsenic contaminated soil, and visualized the data in a site assessment at CMC® industrial chemical contamination, Minneapolis, MN (Cooper, 2007).
  11. October – November, executed continuous measurements of oxygen (O<sub>2</sub>), lower exposure limit (LEL), hydrogen sulfide (H<sub>2</sub>S), hydrogen cyanide (HCN), volatile organic compounds (VOCs), and radiation count rates at Feddeler landfill using air monitors, GPS, a computer on jogging stroller with RAT in order “...to understand the (sic) nature of gas emission points and target single point monitor (SPM) and Summa canister sampling locations.” (Cooper, 2007)

The EPA also used RAT for numerous exercises. The following list comprises some of the exercises where RAT contributed significantly to the outcome of the exercise:

1. April 2005, established the hot zone with a Ludlum® 2241, MultiRae® Plus, DataRam® 4000, wireless router, PC Anywhere® software, and RAT during a radiological fire exercise in order to exercise transferring data from the TOC to a higher echelon located several miles away (Cooper, 2007).

2. June 2005, demonstrated RAT capabilities to local, state, and federal first responders at the Radiation Round-Up Exercise in Idaho Falls, ID (Cooper, 2007).
3. Collected 21,000 data points and received National Nuclear Security Administration Atmospheric Release Advisory Capability (NARAC) plume models within 15 minutes during a Detroit, MI WMD exercise (Cooper, 2007).
4. RAT has also been used during an exercise in an airport. The survey included detectors being placed in Pelican® cases, RAT, and a 900 MHz network. During this exercise, the detectors were stationary running on battery power.

## **2.4 Wireless transmission as a solution to cables**

Using RAT with all the devices connected with cables presents a challenge to the user. First, the user must maintain awareness of the cables in order to prevent slips, trips, and falls. Second, most cables aren't rugged so that the user must not stretch the cable or stress the cable connections. Establishing a 900 MHz network or applying Bluetooth® technologies represent suitable solutions to overcome the challenges associated with the cumbersome cables.

The 900 MHz network "...provides reliable delivery of critical data between remote devices." (XBee-Pro® XSC RF Module, 2008) The range of the XBee-PRO® XSC OEM RF Module is up to 1200 feet indoors or in an urban environment, up to six miles outdoors with line of sight and a 2.1 dBm dipole antenna, and up to 15 miles outdoors with line-of-sight and a high gain antenna (XBee-Pro® XSC RF Module, 2008). The 900 MHz network can be both encrypted and password protected in order to add a layer of security. The range for Bluetooth® is between 10 – 100 meters, "...is able to penetrate solid objects..." and therefore does not require line-of-sight ("Compare with Other Technologies," 2010).

Applying wireless connections would also help reduce the challenges when first responders are suddenly handed a device that they have never previously trained with before. With a longer range network, such as the 900 MHz network, the Survey Team Leader could control the devices remotely. That way the survey member would not have to know how to change the settings on a specific device that they don't normally operate. The survey member would only have to worry about swinging the probe or positioning the detector into a position that it can collect.



### 3. Methods

#### 3.1 ADM300 integration with RAT

Over the last five years, several agencies began creating software programs that record a first responder's instrument readings, time, and GPS location plotting the information in real-time. This enables the TOC to instantly send the site characterization to all jurisdictions and agencies involved in the response. The EPA Region 5 developed RAT which currently integrates with the Ludlum® models 2221, 2241, and 2350-1 and the Fluke® model 451P radiation detectors. The goal of these software programs is to provide the IC and all of its subordinates with a real-time COP.

Currently, a gap exists within the DOD's networked detection capabilities. "Combatant Commanders, with current fielded systems, have limited near-real-time radiological and nuclear detection and identification capabilities... Current detection systems are independent and 'mission specific' ...not networked with other sensors." (Carter, 2008) As a result, tactical-level Commanders have limited situational awareness (detection, location and identification) to react rapidly and provide immediate NUCRAD response within the JOA (Carter, 2008).

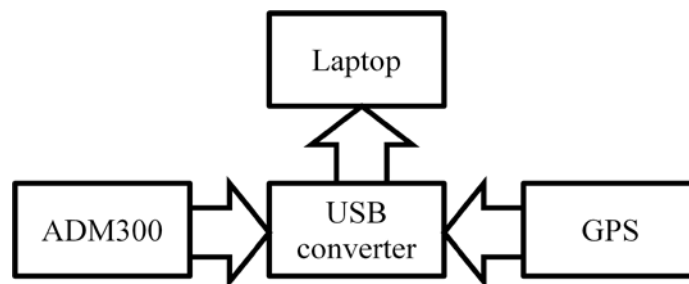
RAT records, in real time, a survey team's location and detector readings on a United States Geological Survey (USGS) teraserver map and simultaneously saves all the data in a Microsoft® Access Database. The database stores the following information:

1. sampling point identification number
2. x and y coordinate
3. name of device
4. results

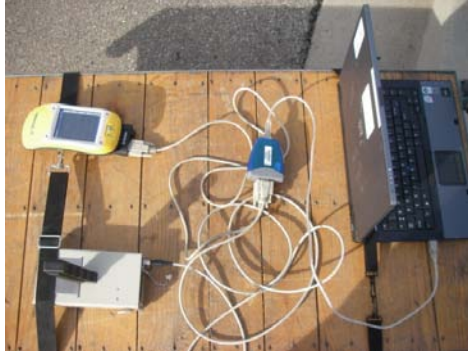
5. units
6. hazard type
7. coordinates in degrees x and y
8. date
9. time
10. Position Dilution of Precision (PDOP)
11. GPS elevation
12. name of GPS device

Contrastingly, the DA Form 1971-R only contains the reading number, location, time, and dose rate. Furthermore, the data in the DA Form 1971-R can only be hand written and must then be entered into a program that could plot the results on a map. The data that is stored in the Microsoft® Access Database is immediately ready to be imported into a plume model.

In order for RAT to work, the survey team must connect a GPS unit and a detector to a computer. The block diagram and the following three photographs show RAT connected to a Trimble® Geo XT GPS and a Canberra® ADM300 using serial cables to a nine pin to Universal Serial Bus (USB) converter to a Hewlett Packard® laptop.



**Figure 3: Block diagram**



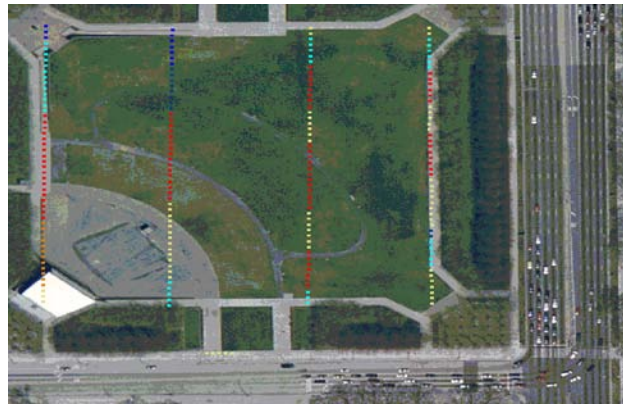
**Figure 4: RAT with GPS and ADM300**



**Figure 5: RAT with GPS and ADM300 on jogging stroller during first experiment**



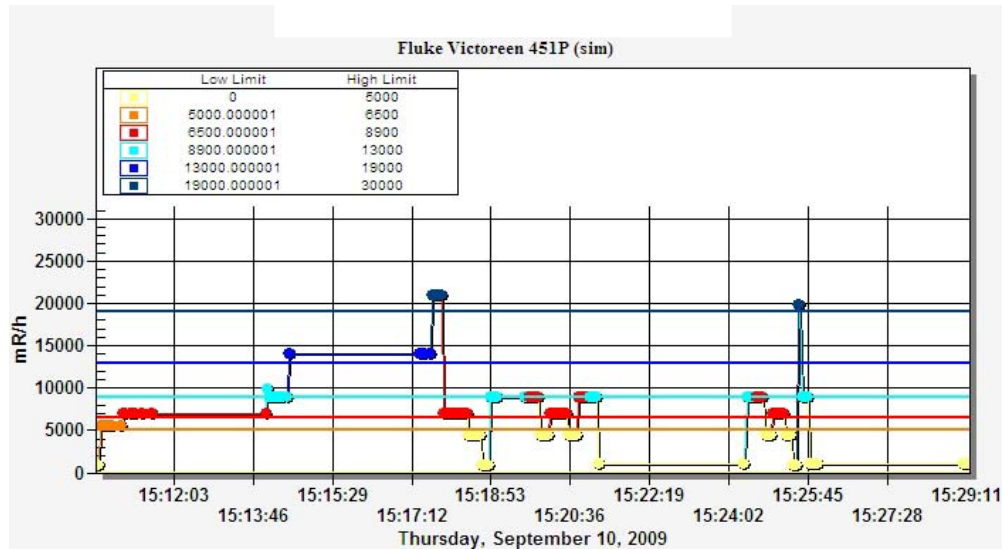
**Figure 6: RAT with GPS and ADM300 on survey cart during second experiment**



**Figure 7: Aerial image displaying the "breadcrumbs" created by RAT**

While in continuous sampling mode, RAT leaves a trail of "breadcrumbs" on the USGS map. The "breadcrumbs" or colored dots represent a threshold that the user sets prior to conducting the survey. Each of the colored dots corresponds to a specific range of readings. Figure 7 displays the "breadcrumbs" from a simulated project. Figure 8 displays these same readings in a trend window. As the survey team navigates across the field leaving colored dots on the image, the trend window simultaneously displays the results in a scaled manner with time on the x axis and rate on the y axis. The trend

window provides the survey team with another means of maintaining a real time representation of their data.



**Figure 8: Trend window from a simulated project**

RAT also displays the threshold legend explaining the readings that correspond to the colored “breadcrumbs.”

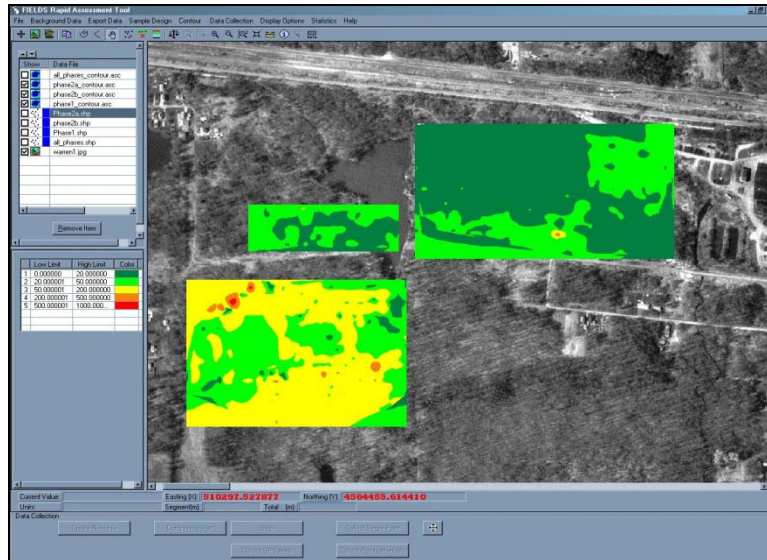
**Table 1: Thresholds corresponding to the “breadcrumbs” in Figure 7**

Color	Low Limit (mR/h)	High Limit (mR/h)
Yellow	0	5000
Orange	5000.000001	6500
Red	6500.000001	8900
Cyan	8900.000001	13000
Blue	13000.000001	19000
Dark Blue	19000.000001	30000

With the data stored in a Microsoft® Access Database, the user may quickly produce a variety of products specific to the IC's requirements in order to most effectively communicate the characteristics of the situation. Figures 9 and 10 display first the data points and then the contours created by interpolating the data. Interpolation offers a solution for the instances when the survey team cannot obtain data at a given location due to restrictive terrain. Also, time constraints may limit the amount of area or thoroughness that a survey team covers in their survey. Therefore, interpolation helps compensate for these shortcomings.



**Figure 9: Sampling points from Warren Recycling® project (Cooper, 2007)**



**Figure 10: Interpolated and contoured data from Figure 9 (Cooper, 2007)**

In order to conduct the experiments with RAT, the ADM300 must first be compatible with RAT. First, this process involved understanding how the Fluke® Victoreen 451P communicates with RAT. Then one can look at how the ADM300 sends data out of its serial port. Next, one searches for the relevant Fluke® files within RAT. Then one copies and modifies those Fluke® files with files specific to the ADM300.

The Fluke® sends data out in the following manner: 1200 bits per second baud rate, seven data bits, no parity, one stop bit, and no flow control. Baud means the “...number of times per second that a line changes state.” (“Introduction to Serial Communications,” 2009) Every time the Fluke® transmits data, it sends 1200 pulses in a second. Therefore, each pulse lasts  $1/1200$  or .00083 seconds. The number of bits represents the size of the data sent out of the ADM300’s serial port. The Fluke® fails to use parity; however, a system with parity serves as a mechanism to conduct “...a small

amount of error checking, to help detect data corruption that might occur during transmission.” (“Introduction to Serial Communications,” 2009) In order to complete the transmission, the Fluke® sends a stop bit in order to inform the receiver that the Fluke® will stop sending data. A stop bit of 1 represents the bit’s period length (“Introduction to Serial Communications,” 2009).

Upon opening Hyper Terminal and by pressing spacebar then T, the Fluke® will send data out the serial port. At this point, the user can view the string of data on the laptop’s screen. The string contains the same information that the user sees on the Fluke’s® display. This includes the current dose rate along with the appropriate units for the display’s bar graph. The bar graph is simply another way for the operator to visualize the dose rate on a scaled bar. Figure 11 below shows the Fluke® display. The top half of the screen displays the current dose rate and the bottom half displays the scaled bar. Figure 11 contains a right limit of 500  $\mu\text{R/h}$ . Therefore, each large tick mark measures 100  $\mu\text{R/h}$ . Should the measurements increase beyond 500  $\mu\text{R/h}$ , the right limit of the scale will increase to 5 mR/h.



**Figure 11: Fluke® display (Victoreen 451P & 451P-DE-SI Ion Chamber Survey Meter Operators Manual, 2005)**

Table 2 displays four data strings. The first two strings contain units of  $\mu\text{R/h}$ . In the case of the strings presented in Table 2, the first reading in the first string measures 255  $\mu\text{R/h}$ . This measurement represents the very first reading that the Fluke® took during the particular time of interest. The Fluke® transmits each subsequent reading in the string until the string reaches its maximum length at the 15<sup>th</sup> measurement of 139  $\mu\text{R/h}$ . Note that the second string appears to cut short after the second measurement. This occurs because the measurements exceeded the bar graph's display limit. Therefore, the last two strings contain units of  $\text{mR/hr}$ .

**Table 2: Fluke® Hyper Terminal Capture**

<b>Bar graph display's right limit</b>	<b>Dose Rate</b>							
500 $\mu\text{R/h}$								
	258	281	245	189	132	092	405	488
5 $\text{mR/h}$								
	0.64	0.66	0.71	0.73	0.71	0.67	0.71	0.68

The ADM300 survey meter contains a serial port capable of transmitting data to an external computer via a Recommended Standard (RS) 232 cable. The data transmits through the serial cable via the following protocol: 300 baud, 8 data bits, no parity, and 1 stop bit (Kulkarni, Hall and O'Brien, 2003). Every time the ADM300 transmits data, it sends 300 pulses per second. Each pulse lasts 1/300 or 0.003 seconds. In most cases we must inform the ADM300 that we want to receive this information. Therefore, to begin



communicating with the ADM300 the user must initiate the following command: CTRL M CTRL J U} (Kulkarni, Hall and O'Brien, 2003). Note that characters are case sensitive. Table 3 displays the various commands and their functions.

**Table 3: ADM300 Commands (Kulkarni, Hall and O'Brien, 2003)**

<b>Command</b>	<b>Function</b>
U	Start Communication
X	Stop Communication
e	Clear accumulated dose
g	Clear/ acknowledge alarms
11....###SE	Change rate alarm set-point to ###SE
22....###SE	Change dose (sic) alarm set-point to ###SE

At this point, the ADM300 will send an output string every two seconds in the following format: nna**RRRSE**\_DDSE\_UUUSE\_RDBG.IxxxxxAxxxx#\_AAASE\_NN] (Kulkarni, Hall and O'Brien, 2003). Table 4 provides the definitions for each symbol within the string. For example, the RRRSE represents the dose rate.

**Table 4: ADM300 string symbol definitions (Kulkarni, Hall and O'Brien, 2003)**

Symbol	Definition
nn	line sequence number
a	ADM-300 identifier
RRRSE	Dose Rate (S = sign, E = exponent, decimal after first R for mR/h, decimal after second R for $\mu$ Sv/h)
space	Separates fields
DDSE	Accumulated Dose (S = sign, E = exponent, decimal after first R, units = mR)
space	Separates fields
UUUSE	Unfiltered Dose Rate (S = sign, E = exponent, decimal after first R, units = mR/h)
space	Separates fields
RDBG	R = rate alarm, D = dose alarm, B = low battery, '.' is used in lieu of previous letters and means the condition does not exist, G = high-range Geiger Mueller tube mode, L = low-range GM tube mode
.	Separates fields
IxxxxxAxxx# (sic)	Debug data field (I = no probes attached; at #, if : instead of hex digit (0-9,a-f), then string at 2 sec later = rate alarm set-point and string at 4 sec later = dose alarm set-point; at #, if 1, then rate alarm set-point; at #, if 2, then dose alarm set-point)
space	Separates fields
AAASE	Alarm setpoint (S = sign, E = exponent, decimal after first R, units = mR/h)
space	Separates fields
NN	Checksum
]	End of string

For clarification and a thorough understanding of the string sent by the ADM300, Table 7 translates the following two sets of strings in Table 5 and Table 6. The RRRSE values are highlighted in each of the strings.

**Table 5: ADM300 sample string (Kulkarni, Hall and O'Brien, 2003)**

<b>nnaRRRSE_DDSE_UUUSE_RDBG.IxxxxxAxxxx#_AAASE_NN]</b>
39a <b>132+0</b> 040-1 113+0 R..L.I00U1BA5509 00000 40]
40a <b>133+0</b> 041-1 138+0 R..L.I00U1QA550: 00000 57]
41a <b>133+0</b> 042-1 149+0 R..L.I00U1WA5501 600-1 44]

**Table 6: ADM300 sample string (Grimaila, 2009)**

<b>nnaRRRSE_DDSE_UUUSE_RDBG.IxxxxxAxxxx#_AAASE_NN]</b>
60a <b>016-1</b> 035-1 044-1 ...L.I00U01A5504 00000 49]
61a <b>016-1</b> 035-1 000-1 ...L.I00U00A5507 00000 4A]

The previous strings translate into the following values. Again, in Table 7, the RRRSE values and the corresponding dose rate are highlighted.

**Table 7: Translation of strings from Tables 5 and 6**

String	Line #	ADM300?	Dose rate mR/h	Dose mR	range GM?	Probes attached? / alarms set?	Alarm set-point	Checksum good?
39a <b>132+0</b> 040-1 113+0 R..L.I00U1BA5509 00000 40]	39	Y	<b>1.32</b>	0.04	yes, no	no, no		Y
40a <b>133+0</b> 041-1 138+0 R..L.I00U1QA550: 00000 57]	40	Y	<b>1.33</b>	0.041	yes, no	no, yes		Y
41a <b>133+0</b> 042-1 149+0 R..L.I00U1WA5501 600-1 44]	41	Y	<b>1.33</b>	0.042	yes, no	no, yes rate alarm =	.6 mR/h	Y
60a <b>016-1</b> 035-1 044-1 ...L.I00U01A5504 00000 49]	60	Y	<b>.016</b>	0.035	no, yes	no, no		Y
61a <b>016-1</b> 035-1 000-1 ...L.I00U00A5507 00000 4A]	61	Y	<b>.016</b>	0.035	no, yes	no, no		Y

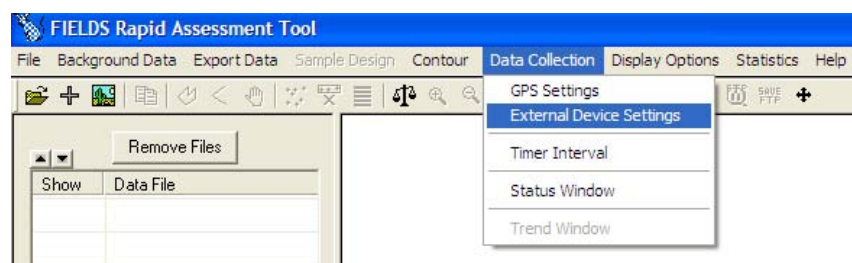
Operators use the unfiltered dose rate when comparing the sensitivities of interchangeable Geiger Mueller tubes. The unfiltered dose rate readings are not provided because they won't be used during this research.

Now that it is understood how RAT communicates with a given device, in this case the Fluke®, and how the ADM300 communicates, one can proceed with the task of interfacing the ADM300 with RAT. The first task, in creating a version of RAT capable of communicating with the ADM300, is locating the Fluke® files within the RAT source

code. This was accomplished by searching for the Fluke® files with Cygwin® software. Cygwin® locates all the files within the source code that contain a specific word. In this case, the searched words included “Fluke®,” “Victoreen,” “Inovision®,” and “451P.”

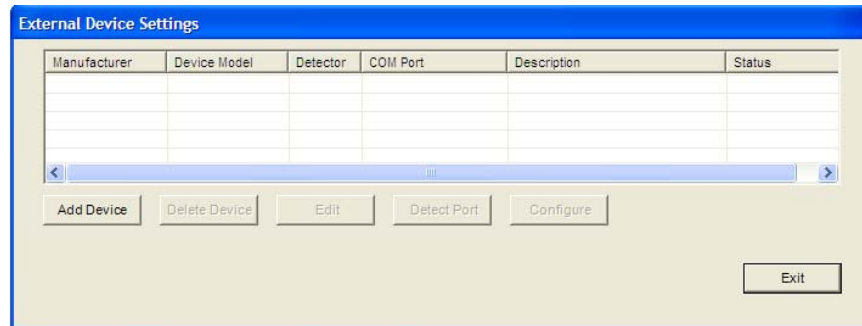
It is important to understand exactly how the RAT code interacts with the Fluke®. Then, by identifying all the appropriate Fluke® files, you are able to copy those files and make the appropriate changes for the ADM300. Once the Fluke® files are located with Cygwin®, Microsoft® Visual Basic allows the user to step through the code in order to determine every subordinate file that the code touches throughout its operation. This ensures that all relevant files are identified.

The following set of screen shots illustrate the visual changes to RAT made under this version. Again, the important task in the development of the experimental apparatus was to be able to connect to a new and different device and ensuring that this new device could communicate with RAT. Upon opening RAT, the user must connect to an external device by clicking “Data Collection” followed by clicking on “External Device Settings.”



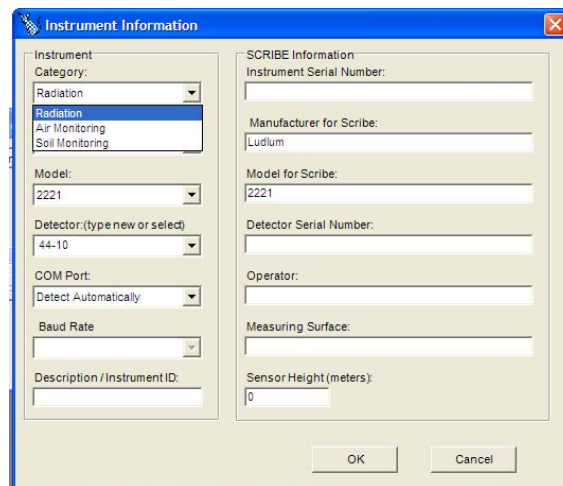
**Figure 12: The first step in adding an external device**

Next, the user clicks on “Add Device.”



**Figure 13: The second step in adding an external device**

The user then selects the appropriate category of detector for the device that they will connect to. In this case, the user selects “Radiation.”



**Figure 14: Selecting a radiation device**

In previous versions of RAT, when the user selected “Radiation,” the manufacturer list included only “Ludlum®” and “Fluke® Victoreen.” However, in this updated version, “Canberra®” is added.

**Instrument Information**

Instrument Category: Radiation

Manufacturer: Ludlum (selected), Fluke Victoreen, 2221

Detector: (type new or select) 44-10

COM Port: Detect Automatically

Baud Rate: [empty]

Description / Instrument ID: [empty]

**Figure 15: RAT without Canberra®**

**Instrument Information**

Instrument Category: Radiation

Manufacturer: Canberra (selected), Ludlum, Fluke Victoreen, Canberra

Detector: (type new or select) [empty]

COM Port: Detect Automatically

Baud Rate: mR/h

Description / Instrument ID: [empty]

**Figure 16: RAT with Canberra®**

In previous editions of RAT, when the user selected “Fluke® Victoreen,” “451P” became available under “Model.” Similarly, in this new updated version of RAT, “ADM-300” was added under “Model” for when the user selects “Canberra®” under “Manufacturer.”

**Figure 17: RAT without ADM300**

**Figure 18: RAT with ADM300**

Several things were done to ensure that RAT worked properly. This involved ensuring the new code compiled without errors and that the executable RAT conducted projects without locking up or crashing. One of the extra checks was ensuring that the checksum matched. This manual calculation is included in Appendix C. Appendix E contains a complete list of all the problems experienced with RAT throughout my testing.



### 3.2 Current procedure

The following summary describes the process a survey team takes in conducting a site characterization (Goodison and Falo, 2008):

An IC directs a survey team "...to determine the location, area affected, and identification (if possible) of chemical agents and/or radiological material in a specific location..." in order to "...determine the extent of any existing health hazards, establish protective control boundaries, and provide data on which to base decontamination requirements." A survey team conducts an area survey in order "...to establish the location and radiation levels associated with one or more isodose rate lines. An isodose rate line is a plotted contour line that depicts the location of some uniform level of radiation or radioactive contamination." A survey member stops advancing once their instrument displays the rate for that specific isodose line and moves "...to the left or right as terrain dictates until the isodose rate line closes." Then, the survey member advances to the next higher or lower rate for the subsequent isodose lines and completes them in the same manner.

Figure 19 captures the process as conducted during the first experiment. The survey member on the left operates the ADM300 detector and measures the dose rate. The survey member on the right determines their location with the GPS in his left hand and speaks into the radio from his right hand. He radios to the TOC, located outside the hot zone, his GPS readings and his partner's ADM300 readings. The recorder located in the TOC records this information along with the time of day on the Department of the Army (DA) Form 1971-R.



**Figure 19: Two man survey without RAT**

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE										DATE	PAGE NO.	NO. OF PAGES
For use of this form, see FM 3-3-1; the proponent agency is TRADOC												
SURVEY PARTY OR MONITORING UNIT DESIGNATION										MONITOR (Print name)		
MAP USED			TYPE OF VEHICLE OR OTHER SHELTERING				INSTRUMENT TYPE					
READING NO.	LOCATION	TIME	DOSE RATE ( $\mu$ Sv/h)		DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE ( $\mu$ Sv/h)		DO NOT USE*	
1						16						
2						17						
3						18						
4						19						
5						20						
6						21						
7						22						
8						23						
9						24						
10						25						
11						26						
12						27						
13						28						
14						29						
15						30						
REMARKS												
* DO NOT USE. For control party only												
CORRELATION FACTOR DATA												
LOCATION	READING NO.	DOSE RATE ( $\mu$ Sv/h)		CF*	LOCATION	READING NO.	DOSE RATE ( $\mu$ Sv/h)		CF*			
		INSIDE	OUTSIDE				INSIDE	OUTSIDE				

DA FORM 1971-R, SEP 94 EDITION OF SEP 86 IS OBSOLETE

**Figure 20: DA Form 1971-R**

Figure 21 illustrates the recording procedures as conducted during the second experiment. The survey member on the right operates the ADM300 and measures the dose rate. The survey member on the left determines their location with the GPS and time of day, both of which are located on the clipboard. He records his GPS readings, time of day, and his partner's ADM300 readings on the DA Form 1971-R.



**Figure 21: Stationary two person survey without RAT**

The following two photos illustrate the difficulty that the survey members experience while looking through their masks and reading small screens.



**Figure 22: With GPS and without RAT**



**Figure 23: With ADM300 and without RAT**

Figure 24 shows the difficulty survey teams face while trying to maintain data on a clean and dry DA Form 1971-R. The actual DA Forms are located in Appendix J. Note the poor quality of the handwriting. This results from writing on clipboard with layers of gloves and numb hands from extremely cold weather.

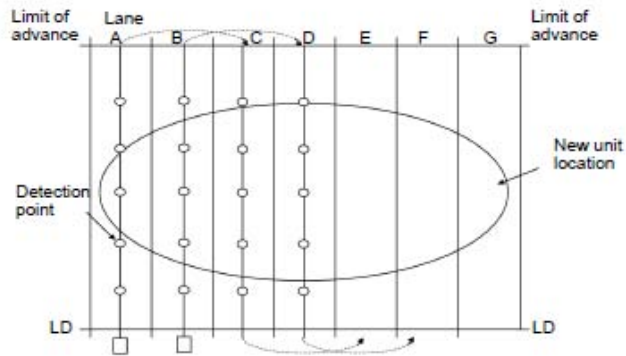


**Figure 24: Maneuvering two person survey without RAT**

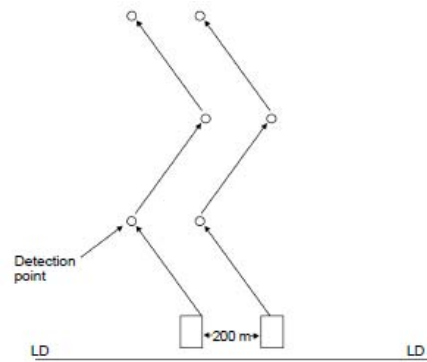
### **3.3 Experimental conditions**

This experiment compared six different survey techniques with and without RAT. The survey team executed each technique with or without RAT in accordance with Tables G1 and G2 (Appendix G). The execution synchronization matrices presented in Tables G1 and G2 assigned each survey team a specific scenario either with or without RAT in order to ensure that the teams were scrambled and not always executing exclusively with or without RAT. The 52<sup>nd</sup> WMD-CST executed the scenarios as indicated in Table G1. Personnel were dressed in JSLIST with a PAPR. The BEEs from the 88 Aerospace Medicine Squadron (AMDS/SGPB) executed the scenarios as indicated in Table G2. The uniform for the BEEs included Occupational Safety and Health Administration (OSHA) Level B with SCBA.

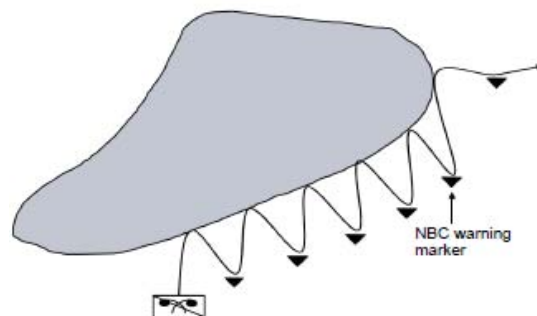
The following six figures display each survey technique.



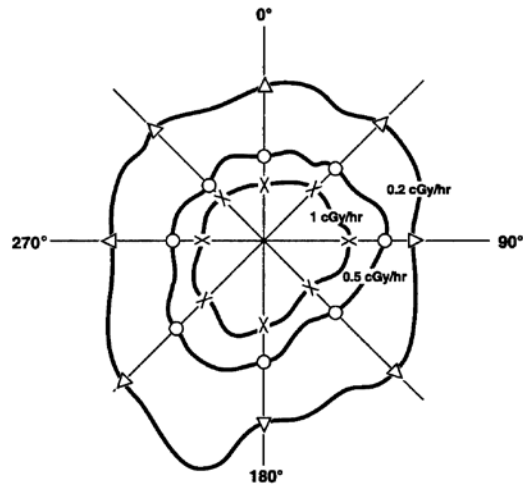
**Figure 25: Lane (Lillie, Hanlon and Kelly, 2004)**



**Figure 26: Zigzag (Lillie, Hanlon and Kelly, 2004)**

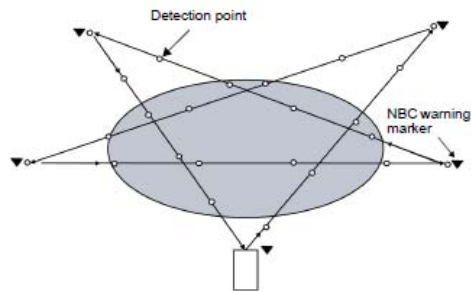


**Figure 27: Bounce and bypass (Lillie, Hanlon and Kelly, 2004)**

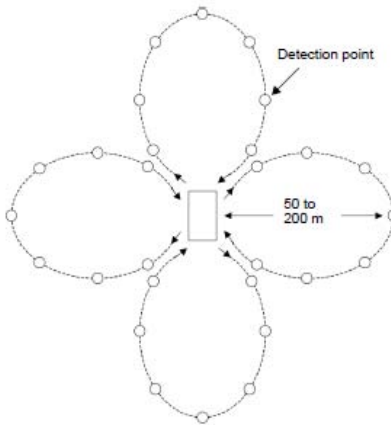


*Figure A-II. Radial Plot*

**Figure 28: Radial (Reimer, Koenig and Anderson, 1996)**



**Figure 29: Star (Lillie, Hanlon and Kelly, 2004)**



**Figure 30: Cloverleaf (Lillie, Hanlon and Kelly, 2004)**

Both the WMD-CST and the BEEs utilized the same detection protocol in order to standardize the surveying of both non-RAT and RAT teams. The detection protocol involved holding the ADM300 to the source with the beta ( $\beta$ ) shield open until the one-tenths digit stopped increasing for five seconds. The  $\beta$  shield open allows  $\beta$  to pass and enter the detector. Contrastingly, closing the  $\beta$  shield prevents  $\beta$  from entering the detector. The purpose of the five second protocol was to stabilize the detector and to standardize data collection from survey team to survey team. The five second time was selected because the readings seemed not to increase significantly after five seconds. For example, if the readings measured 1.12 1.18 1.19 1.00 0.99 1.10 1.15 1.19 1.19 all within a five second count, the survey member would return the source to its location and proceed to the next task. However, for example, if the readings measured 1.12 1.18 1.19 1.00 0.99 1.22 before the survey member completed a five second count, the survey member would restart the five second count at the 1.22 reading because the one-tenths digit increased between the 0.99 and 1.22 readings.

The integrity of the data sent from the ADM300 to RAT was checked through 26 different projects. The nine days of projects collected 9,642 data points and every reading witnessed on the ADM300 screen was seen on the RAT screen and thus recorded into RAT's Microsoft® Access Database. Appendix F lists the number of points sampled for each project throughout the data integrity testing.

The sources were Cesium-137 check sources. Each source measured approximately 1mR/hr. In total, 113 Cesium-137 check sources were used. The sources were placed in envelopes as indicated in Figure 31. The pen-shaped and sized sources were placed at the bottom of the envelope with the actual source located at the lower right corner of the envelope, when the survey member secured the envelope. Figure 31 shows the survey member gripping the pen-like sources with his left thumb over the sources and envelope and his remaining left four fingers under the sources and envelope.



**Figure 31: Cesium-137 sources in envelope**



The maximum number of sampling points for any scenario was 28. This number of sampling points was chosen because it represented an appropriate amount of data points in order to evaluate the effectiveness of RAT. Therefore, there were 28 envelopes as indicated in Table 8.

**Table 8: Number of envelopes containing a given number of sources**

									Total
Envelopes	4	5	2	5	4	4	3	1	28
Sources per envelope	1	2	3	4	5	6	7	8	
Sources	4	10	6	20	20	24	21	8	113

The WMD-CST iterations occurred on a typical late fall day of less than 10 hours of daylight. This presented significant time restraints in completing the scenarios in a single day's daylight. Table 9 displays the light data for the exercises. Therefore, this limited amount of daylight created a need for thorough administrative planning in order to ensure that the survey teams completed their experiments in one day.

**Table 9: Light data for experiments ("Sunrise and Sunset for U.S.A. - Ohio – Columbus," 2009)**

Date	Before Morning Nautical Twilight (BMNT)	Sunrise	Sunset	End of Evening Nautical Twilight (EENT)
23Nov09	0624	0726	1710	1813
15Dec09	0642	0747	1708	1812

The amount of time required to move sources from one scenario to the next coupled with the fewer daylight hours created a challenge. Therefore, a detail of soldiers moved the sources from the sampling points of one scenario to the sampling points of the next scenario. The evening prior to the exercise, each sampling point was identified with a traffic cone. Each traffic cone was marked by a legal sized sheet of paper that identified the sampling point by letter (A to Z) and the name of the scenario (lane, zigzag, bounce and bypass, radial, star, or cloverleaf). Therefore, a traffic cone clearly marked every survey point for the WMD-CST survey teams and the soldier detail assigned to administratively move the sources from one scenario to the next. The soldier detail moved the sources between scenarios as quickly as possible in order to ensure that there was no delay in the start of the following survey. For example, once the survey team completed the lane survey with RAT, the soldier detail moved the sources from the cones on the lane scenario and placed the sources under the cones on the zigzag scenario before the survey team began surveying the zigzag scenario without RAT.

Traffic cones clearly marked every waypoint for the survey teams. It was important to create well identifiable points for the details and survey teams in order to prevent skewed data occurring from time variations in locating survey points.



**Figure 16: Example of a marked traffic cone**

In an effort to reduce administrative time for the detail, each envelope was assigned an envelope number and the number of sources per envelope. The following tables display this information.

**Table 10: Number of sources present in envelopes 1 - 14**

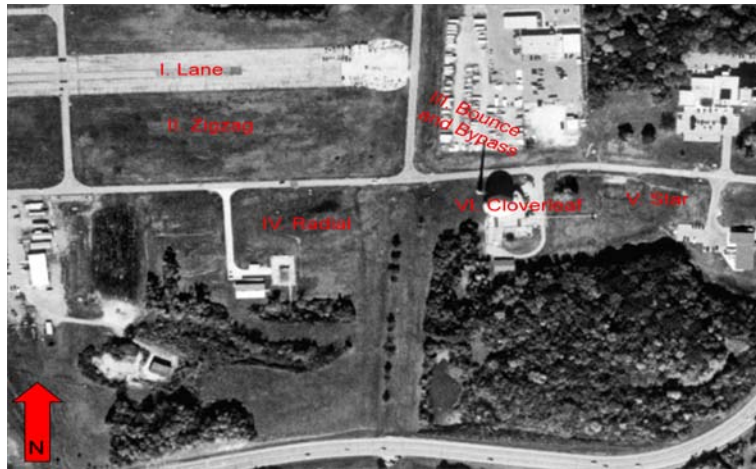
Envelope #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of Sources	1	1	1	1	2	2	2	2	2	3	3	4	4	4

**Table 11: Number of sources present in envelopes 15 - 28**

Envelope #	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Number of Sources	4	4	5	5	5	5	6	6	6	6	7	7	7	8

The letter and number codes on Figures 35, 37, 39, 41, 43, and 50 correspond to the letter on the traffic cone and the number of sources in the envelope for that particular sampling point.

Figure 33 displays the Concept of the Operations for the exercise. The exercise included six different scenarios. Each scenario involved a different survey technique. The following six sections describe the scheme of maneuver for each of the six scenarios.



**Figure 33: Concept of the Operations**

### **3.4 Lane Survey Technique**

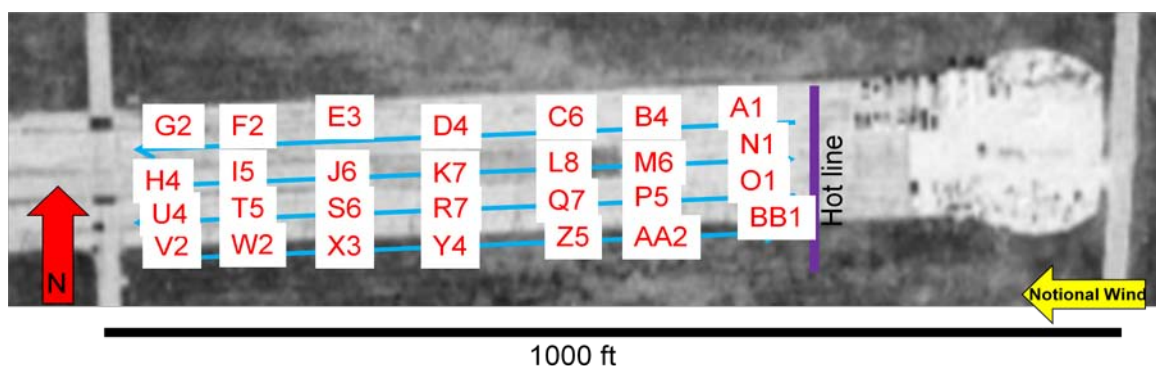
The first scenario included the lane survey technique. The photo in Figure 34 shows the steep slope of the accelerator runway (constructed of asphalt). As seen in the photo, the asphalt contains many cracks. Nonetheless, this surface represents the least restrictive of any of the scenarios.



**Figure 34: Lane scenario terrain**

The distance between each sampling point measures approximately 30 meters. The length of a single leg measures approximately 180 meters. Four legs total less than 750 meters.

Figure 35 displays the relative locations of every sampling point as indicated with letter A through BB. The number indicates the number of Cesium-137 check sources located at each sampling point for the WMD-CST scenarios. For the BEE scenarios, the Survey Team carried and monitored the envelope with that specific number of sources up to the designated location.



**Figure 35: Lane scenario layout**

Table 12 displays the distribution of the 28 envelopes containing various amounts of Cesium-137 sources. These 28 envelopes were used for each scenario. Table 12 displays the quantity of a given type of envelope for each scenario. For example, the lane scenario included four envelopes with each containing one source, five envelopes with each containing two sources, two envelopes with each containing three sources, etcetera.

**Table 12: Quantity of envelopes with a given amount of sources for each scenario**

Number of sources per envelope	1	2	3	4	5	6	7	8
Lane	4	5	2	5	4	4	3	1
Zigzag	0	5	2	5	4	4	3	1
Bounce and bypass	4	3	0	0	0	2	3	1
Radial	0	0	0	5	4	4	3	1
Star	1	5	2	5	4	4	3	1
Cloverleaf	4	5	2	5	4	4	3	1

Prior to execution, the Observer/Controller (OC) provided the survey teams the following Tactical Vignette:

1. An RDD exploded on the accelerator runway.
2. Conduct a site characterization of the area in order to determine the radiation levels.

The Tactical Vignettes were created for two reasons. First, they provided the survey teams with a succinct mission statement for their surveys. Second, the Tactical Vignette assists the practitioner in gaining an understanding of how RAT may be applied to enhance military tactics.

### **3.5 Zigzag Survey Technique**

The second scenario included the zigzag survey technique. The area's location was next to the accelerator runway. Therefore, the zigzag and the lane scenarios both shared similar challenges with the same steep slope. Figure 36 shows the field where the survey teams conducted the zigzag survey. The most significant difference between this field and the accelerator runway relate to the surface. As seen in the photo, the grass was very thick. The soil was saturated and extremely muddy at the base of the hill. The slope was long and gradual like the slope on the accelerator runway.



**Figure 36: Zigzag scenario terrain**

The distance between each sampling point measured approximately 50 meters. The length of a single leg measured approximately 150 meters. Six legs total less than 1000 meters.

Figure 37 displays the relative locations of every sampling point (A - X) as well as the number of Cesium-137 check sources. The number next to the letter represents the number of sources located in the envelope at that particular point.



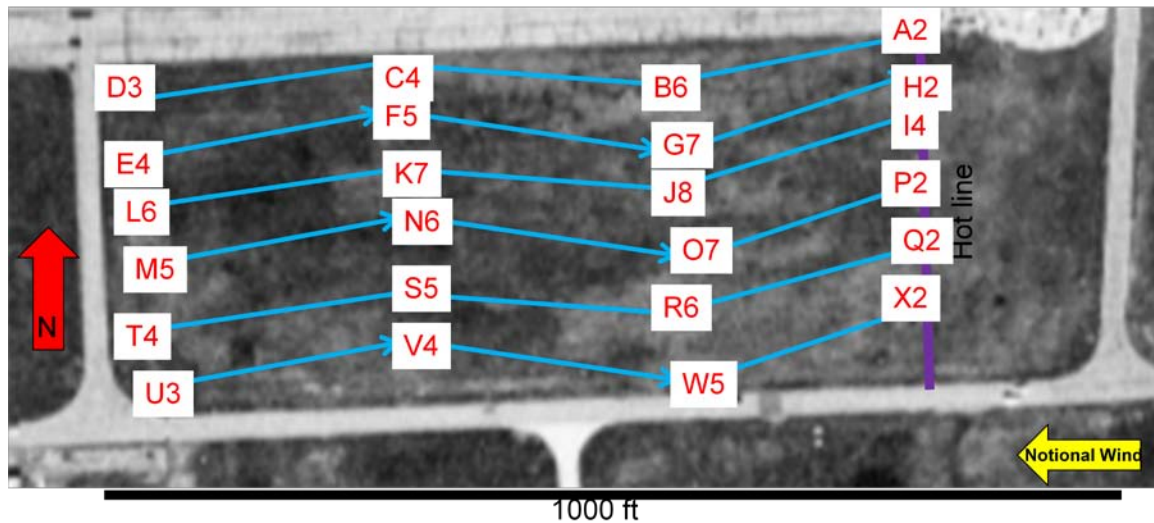


Figure 37: Zigzag scenario layout

Table 12 displays the distribution of the Cesium-137 sources for the 28 envelopes.

Prior to execution, the OC provided the survey teams the following Tactical

Vignette:

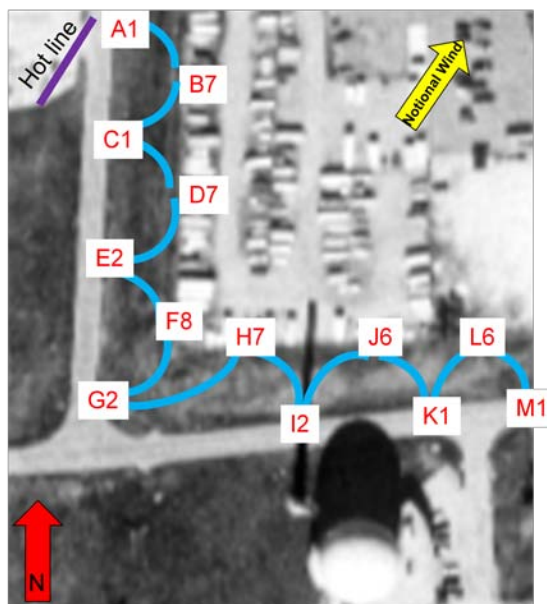
1. An RDD exploded on the base's Forward Arming and Refueling Point (FARP).
2. Conduct a site characterization of the area in order to determine the radiation levels.

### 3.6 Bounce and Bypass Survey Technique

The third scenario included the bounce and bypass survey technique. Figure 38 shows the gentle slope from the road to the fence line. However, from point A to F, the slope is somewhat steeper. The grass is also shorter than the second scenario. The ground is hard and generally lacks any mud with the exception of a few mud puddles near the road. Overall, this surface represents a mid range difficult terrain due to the difficulty in pushing the cart up the slope.



**Figure 38: Bounce and bypass scenario terrain**



**Figure 39: Bounce and bypass scenario layout**

The distance between each sampling point measures less than 30 meters. The length of the entire survey totals less than 400 meters.

Figure 39 displays the relative locations of every sampling point (A through M) as well as the number of Cesium-137 check sources.

Table 12 displays the distribution of the Cesium-137 sources for the 28 envelopes.

Prior to execution, the OC provided the survey teams the following Tactical Vignette:

1. A suspected Special Nuclear Material (SNM) facility under the previous regime is located along Main Supply Route (MSR) Waldo. Currently, the host nation government refuses to allow Coalition Forces (CF) to enter the facility.
2. Determine a 1mR/hr boundary in order to establish protective control boundaries along MSR Waldo.

### 3.7 Radial Survey Technique

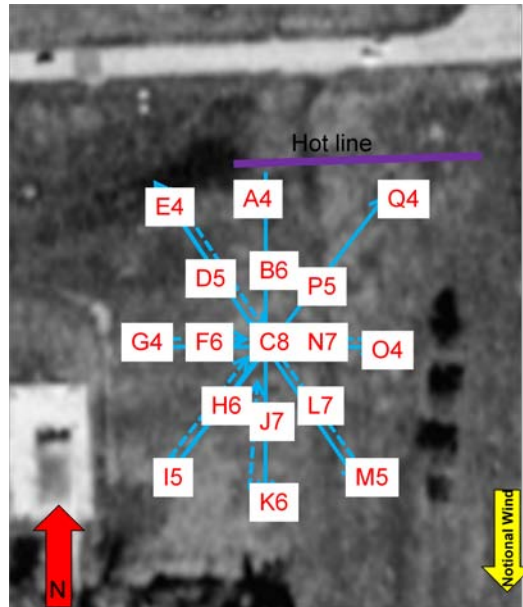
The fourth scenario included the radial survey technique. Figure 40 shows the flat short grassy orchard. The surface was totally flat and the ground was hard. After the accelerator runway, this surface represents the least restrictive of the remaining five scenarios.



**Figure 40: Radial scenario terrain**

The distance between each sampling point measured less than 15 meters. Each radius measured approximately 30 meters. However, on six of the eight legs, the survey team backtracked over those legs. Therefore, the total distance traveled measured approximately 420 meters.

Figure 41 displays the relative locations of every sampling point (A - Q) as well as the number of Cesium-137 check sources.



**Figure 41: Radial scenario layout**

Table 12 displays the distribution of the Cesium-137 sources for the 28 envelopes.

Prior to execution, the OC provided the survey teams the following Tactical

Vignette:

1. Local law enforcement identified a suspicious research glove box in the middle of the field.
2. Conduct a quick site characterization of the area in order to determine any radiation levels.

### **3.8 Star Survey Technique**

The fifth scenario included the star survey technique. The terrain consisted of thick grass with two hills. On the approach to point A, the survey team encountered the first hill. The second hill runs from point P to F to U as seen in Figure 42. This hill would not present many problems for the survey teams pushing or pulling the survey cart because of the hill's short duration. The star scenario's surface represented a more

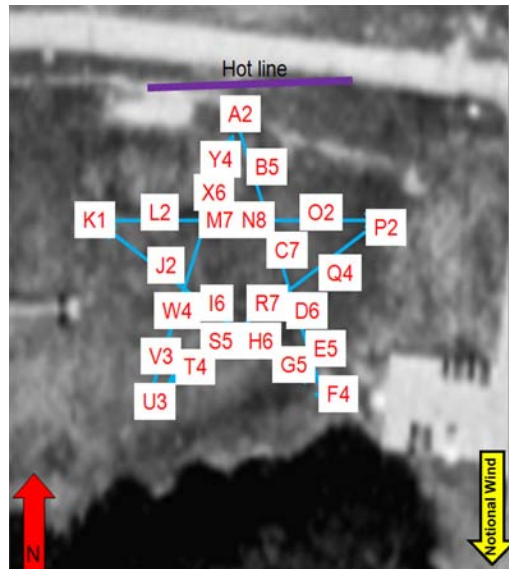
challenging surface than the radial scenario and a less challenging surface than the bounce and bypass scenario.



**Figure 42: Star scenario terrain**

The distance between each sampling point measured approximately 10 to 20 meters. The length of a single leg measured approximately 100 meters. Five legs totaled approximately 500 meters.

Figure 43 displays the relative locations of every sampling point (A - Y) as well as the number of Cesium-137 check sources.



**Figure 43: Star scenario layout**

Table 12 displays the distribution of the Cesium-137 sources for 28 envelopes.

Prior to execution, the OC provided the survey teams the following Tactical

Vignette:

1. CF plan on establishing a squad sized Patrol Base (PB) at this location. However, an interview with an LN revealed that a radiological accident occurred in the vicinity of this area.
2. Quickly determine the levels of contamination in order to determine whether or not the levels of radiation are restrictive.

### **3.8 Cloverleaf Survey Technique**

The sixth and final scenario included the cloverleaf survey technique. Figure 44 shows the hill located on the first loop. This is the same hill that was located leading from the road to the fence in the bounce and bypass survey. Figure 45 shows the second loop that overlooks the orchard from the radial survey. This grass is the same as that in the orchard. Figures 46 and 47 show the third loop. Notice the steep descent in the third



loop. The net covering the straw across the road presents a potential hazard while climbing the hill. Figures 48 and 49 show the steep slope of the fourth loop. This scenario would present challenges for the RAT survey teams while ascending and descending the hills. This scenario would also introduce new problems with the GPS as the survey teams approach the tall reactor building and the recycling and disposal building located on the top of the photo in Figure 46.



**Figure 44: Cloverleaf scenario loop number one terrain**



**Figure 45: Cloverleaf scenario loop number two terrain**



**Figure 46: Cloverleaf scenario first half of number three terrain**



**Figure 47: Cloverleaf scenario second half of loop number three terrain**



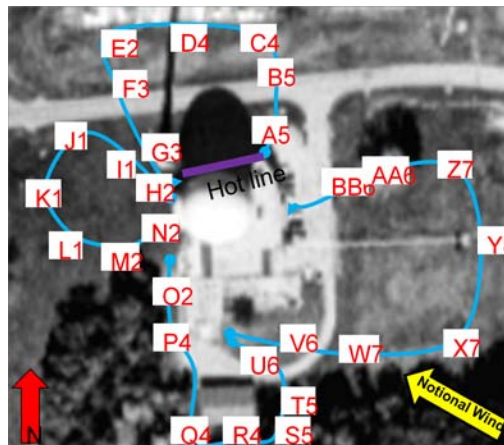
**Figure 48: Cloverleaf scenario first half of loop number four terrain**



**Figure 49: Cloverleaf scenario second half of loop number four terrain**

The distance between each sampling point measured approximately 20 meters. The length of a single loop measured approximately 150 meters. Four legs totaled approximately 600 meters.

Figure 50 displays the relative locations of every sampling point as well as the number of Cesium-137 check sources.



**Figure 50: Cloverleaf scenario layout**



Table 12 displays the distribution of the Cesium-137 sources for the 28 envelopes.

Prior to execution, the OC provided the survey teams the following Tactical

Vignette:

1. A nuclear detonation occurred 750 km east of your C2 facility that is located in restricted terrain.
2. Conduct a site characterization in order to ensure that the C2 facility is free of contamination.

## 4. Results and Analysis

### 4.1 Discussion

A significant amount of data was obtained utilizing seven teams wearing two different uniforms, conducting 24 iterations of six different scenarios over a two day period.

While developing the detection protocol, the ADM300 was placed to the source for over a minute. The readings after five seconds did not vary significantly to the readings taken after one minute.

Apart from the variation in uniform, a significant difference between the two experiments relates to the scheme of maneuver executed by the WMD-CST and BEEs. The WMD-CST survey teams sampled individual points. They navigated to a sampling point, secured the source, and measured the sample in accordance with the detection protocol. These scenarios represented areas of up to 28 different contaminated points. The BEE survey teams sampled continuously as if monitoring a plume of contamination. Identical to the WMD-CST survey teams, the BEEs navigated to the same waypoints. However, they did not reach down and secure the sources. In order to mimic a plume of contamination, the OC handed the source to a BEE survey member and the survey team navigated to the next waypoint while continuously measuring the source. The second survey member recorded their location and time on the DA Form 1971-R. Once the one-tenths digit stopped increasing for five seconds, the second survey member recorded the readings on the DA Form 1971-R. The first survey member continued to hold the

ADM300 to the source while en route to the next waypoint. If while navigating to the next waypoint, the ones digit increased, the survey team stopped and recorded the time, location, and readings. At this point, the survey team would not wait five seconds. They would simply record the time, location, and readings and continue to the next waypoint.

The most obvious difference between the non RAT and RAT iterations relates to the quality of the products. As seen earlier, the products produced by RAT warrant its use as a survey tool. Upon completion of the experiments, the data was analyzed. The overall time that the survey teams took to complete each scenario without and with RAT was compared. Specific sampling points, routes between sampling points and waypoints, and the time taken to survey the specific point or area were compared and analyzed.

## **4.2 Results**

The following table displays the time taken to execute each scenario and the percent change in time when the survey team executed with-out and with RAT. This decreased time reveals two significant findings. First, this data reveals how much quicker first responders can conduct a site characterization using RAT. This will lead to the IC receiving a COP much quicker. Second, this decreased amount of time will limit the exposure on the first responders in the hot zone.

**Table 13: Comparison of survey completion times between without RAT and with RAT**

<b>Survey Technique</b>	<b>Time in minutes without RAT to complete survey</b>	<b>Time in minutes with RAT to complete survey</b>	<b>% increase or decrease in time to complete survey</b>
WMD-CST Lane	31	20	Decrease 35%
BEE Lane	37	21	Decrease 43%
WMD-CST Zigzag	24	30	Increase 25%
BEE Zigzag	37	19	Decrease 49%
WMD-CST Bounce and Bypass	16	13	Decrease 19%
BEE Bounce and Bypass	15	10	Decrease 33%
WMD-CST Radial	15	16	Increase 7%
BEE Radial	24	11	Decrease 54%
WMD-CST Star	19	17	Decrease 11%
BEE Star	22	8	Decrease 64%
WMD-CST Cloverleaf	23	19	Decrease 17%
BEE Cloverleaf	41	14	Decrease 66%

As expected, the lane survey revealed the most significant results. This occurred because of the unrestricted terrain. Specifically, the relatively smooth surface of the accelerator runway failed to present a significant disadvantage to the survey team pushing or pulling the survey cart. In fact, the WMD-CST survey member pushing the cart appeared to catch his breath and recompose himself when the survey team halted at a given survey point. Fatigue caused the BEE survey member pulling the cart to slow down during the ascent of the second and fourth legs. However, the cart pulling survey member's reduced speed appeared to assist the survey member operating the ADM300

who required a slower pace in order to maintain proper survey techniques while maintaining positive control of the ADM300 serial cable. In other words, in the case of continuous dismounted monitoring, the survey member operating the detector played more of a role in decreasing the rate-of-march than any factor relating to the need for a survey cart to transport RAT.

It should be noted that for the WMD-CST lane and star scenarios, that the units for four points for the former and one point for the latter were incorrectly reported as  $\mu\text{R/h}$  vice  $\text{mR/h}$ . Also, upon scrutinizing the entries on the BEE DA Form 1971-Rs, it should be noted how difficult it is to read the entries that were made by the survey members in the hot-zone. This is partly attributed to the extremely cold weather causing numb fingers.

Finally, there were no issues with the integrity of the ADM300 data sent to RAT. However, as revealed in Figure 62 for the WMD-CST cloverleaf survey, it must be noted that there were some issues with the GPS. This was most likely caused by the proximity of the tall dome of the reactor building, the tall smoke stack, and the heavy wood line. RAT plotted six above background points on the road when in fact there were no sample points located on the road. Also, RAT plotted four background points on the road off of the line-of-march. The proximity to the tall smoke stack most likely caused these GPS issues. RAT plotted eight above background points in the wood-line west of the reactor building off of the line-of-march. Also, RAT plotted five above background points in the wood-line south of the recycling building. The proximity to the buildings and the wood-line most likely caused these GPS issues. These GPS issues could be combated by lasing

the targets with a GPS device or by integrating other GPS sensors capable of providing accurate coordinates.

### **4.3 Lane Survey**

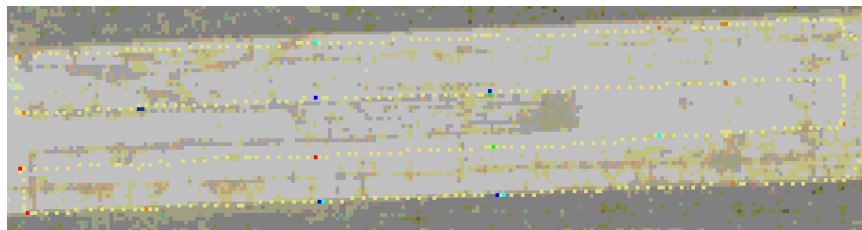
I anticipated that the results from this scenario would be the most revealing. Due to the least restrictive paved asphalt surface, the RAT survey teams should complete the scenario significantly quicker than the non RAT survey teams.

Figures 51 and 52 display the images produced by RAT. In addition to these quality site characterizations produced, RAT also stores all of the sample data in a Microsoft® Access Database. The two photos appear different due to the way in which the survey team executed the scenario. For the first image, the survey team detected the sources at the specific sampling points. However for the second image, the survey team detected the sources while en route to a given waypoint. Therefore, the first image contains several hundred background points and only 28 sampling points. However, zooming in on a given point reveals several more points next to each of the 28 sampling points. As discussed previously, the ADM300 sends data out of the serial port every two seconds. Therefore, RAT plots a point for every reading every two seconds. The second image contains several hundred sampling points. Again, because the survey team monitored en route to a waypoint, the image below appears more like a plume. The images below and the Microsoft® Access Database provide a far more accurate site characterization to the TOC and IC than the DA Form 1971-R located in Appendix J. This ensures that the IC receives a good assessment of the contamination in the hot zone.

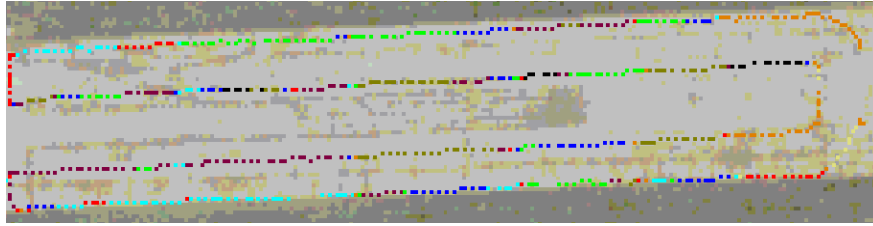
This will enable the IC to make well informed decisions based on a thorough understanding of the contamination present.

Figures 51 and 52 represent the results from the lane surveys conducted with RAT. Similar to Figure 7, these two figures provide an accurate image of the radiation levels present on the site. Each dot or “breadcrumb” corresponds to a specific threshold. The operator may edit the defaulted thresholds to preferred or more appropriate ranges and colors. These thresholds are similar to the thresholds listed in Table 1. However, these dots or “breadcrumbs” represent much lower levels due to the fact that these were test sources and not the simulated test conducted while obtaining the data in Figures 7 and 8 and Table 1.

Figures 51 and 52 display the large amount of survey points collected. Each dot corresponds to a row in the Microsoft® Access Database. Figure 52 appears different than Figure 51 because the BEEs maintained constant contact with the sources in order to mimic a plume of contamination. The WMD-CST established contact with the sources only at the 28 traffic cones. The yellow dots in Figure 51 represent background levels.



**Figure 51: WMD-CST lane survey**



**Figure 52: BEE lane survey**

Table 14 displays the significant data obtained during the scenario. The table shows a 35% and 43% reduction time in the survey time for the WMD-CST and BEEs respectively. Also, note the significantly larger number of points surveyed using RAT vice without RAT. The reason for the increased number of points surveyed when using RAT is that when RAT is on continuous survey mode it collects all the data that the device sends to RAT. As discussed previously, the ADM300 sends a data string every two seconds. Therefore, RAT will record an ADM300 measurement every two seconds. These recordings are stored in the Microsoft® Access Database and are represented by the colored “breadcrumbs” on the image.

**Table 14: Lane survey data**

	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	31	28	
WMD-CST w/ RAT	20	614	12 (3 were consecutive)
BEEs w/o RAT	37	37	
BEEs w/ RAT	21	619	16 (4, 2, and 2 were consecutive)



The results from the lane scenario produced the most significant decrease in survey time for both the WMD-CST and BEE iterations. This resulted from the smooth and unrestricted terrain. These results would be significantly magnified if the scenario was conducted while mounted on a vehicle.

#### **4.4 Zigzag Survey**

Despite the increased length of this scenario, it was anticipated that the results would be less revealing than the lane survey. The thick grass and the mud would cause problems while pushing or pulling the survey cart. Due to the increased time required to complete the survey, the effects of the PPE on the survey member would become a factor.

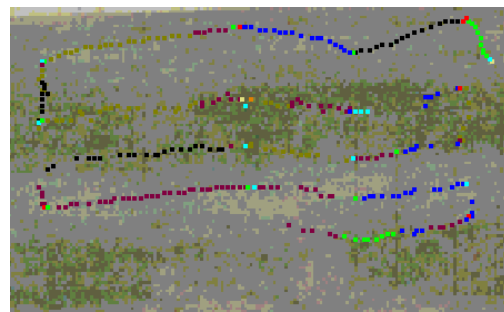
The zigzag scenario resulted in a 25% increase and 49% reduction in the survey time for the WMD-CST and BEEs, respectively, when comparing the iterations without RAT to the iterations with RAT. The 25% increase in time seemed surprising. This represented an unexpected result of the data. The terrain caused this increase in time. For the 24 minute non RAT iteration, the WMD-CST survey team simply walked from point to point and only concerned themselves with arriving expeditiously at that point and monitoring the sample. However, for the 30 minute RAT iteration, the survey team pushed the cart across thick tall grass over muddy rutted terrain. Throughout their navigation and monitoring, they ensured that the equipment remained secured to the cart. These factors caused the survey team to travel at a decreased rate-of-march compared to the survey team not using RAT.

During this scenario, RAT appeared to influence the survey times. This was not a result of RAT directly. Instead, the increased time resulted from the fact that the survey teams using RAT pushed or pulled a survey cart. The challenges of the survey cart could be overcome by the survey teams using wearable tablet personal computers (PC) on a harness or by applying other more mobile methods such as backpacks.

As discussed previously, traffic cones clearly marked the survey points and waypoints. Nonetheless, Figure 53 reveals a need to explore another of RAT's capabilities, namely using RAT to navigate. On the start of the third leg, the navigator led the survey team to a previous point on the second leg rather than the subsequent point on the third leg. RAT contains the ability for the Survey Team Leader to manually identify sampling points on the image allowing the survey team to navigate toward those sampling points. A high resolution heads-up display would allow this capability to be tested and ultimately maximized.



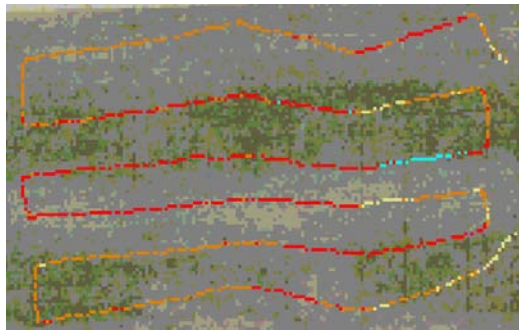
**Figure 53: WMD-CST zigzag survey**



**Figure 54: BEE zigzag survey**

When compared to Figure 53, Figure 54 reveals an incomplete site characterization with a significant loss of data. This occurred because the ADM300

serial cable became inoperable. From this point forward, the BEE survey teams with RAT executed the scenarios using a Fluke® Victoreen 451P. Over the course of the experiments, two ADM300 serial cables broke. The first cable broke due to the operator's unfamiliarity with the connections while attempting to unplug the cable from the ADM300. The second cable stopped working for no explainable reason. The cable's length totaled less than three feet. The cable may have become stressed from repeated tension during the surveying. Nonetheless, the issues with the cables address the need for more durable cables and connections and the need to explore wireless connections.



**Figure 55: BEE zigzag survey with Fluke®**

Table 15 displays the significant data from the zigzag scenarios. The WMD-CST with RAT iteration collected 888 points in 30 minutes and the second BEEs with RAT iteration collected 969 points in 19 minutes. This may appear confusing as to how RAT collected more points in less time during the BEEs iteration. This occurred because at this point in the exercise the ADM300 cable broke and the survey team switched to the Fluke® Victoreen 451P. The Fluke® sends strings of data out every one second instead

of every two seconds as in the case of the ADM300. Therefore, RAT records approximately twice as many sampling points when using the Fluke vice the ADM300. For example, the WMD-CST iteration with RAT and ADM300 collected 888 points in 30 minutes. This equals 29.6 points per minute. The BEE iteration with RAT and Fluke® collected 969 points in 19 minutes. This equals 51 points per minute.

The number of points lost in the RAT iterations remained low during the zigzag survey. These resulted from a lost GPS signal. Typically, the signal was lost due to a survey member standing directly over the GPS device. Most of the points lost were not consecutively grouped together for more than three points. Therefore, a significant portion of the site characterization was not lost due to lost GPS signal. Despite the lost GPS signal, RAT still records the data from the detector. Therefore, the user could go back and interpolate the locations of these lost GPS points and manually estimate their locations based on the previously known and next know GPS locations.

**Table 15: Zigzag survey data**

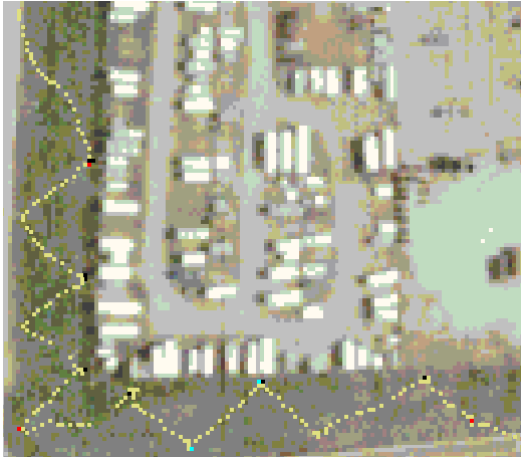
	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	24	24	
WMD-CST w/ RAT	30	888	24 ( 2, 3, 2, 2, and 2 were consecutive)
BEEs w/o RAT	37	32	
BEEs w/ RAT	12 (incomplete)	379	54 (2, 8, 3, 2, 2, 3, 4, 3, 2, and 2 were consecutive)
BEEs w/ RAT	19	969	0

#### **4.5 Bounce and Bypass Survey**

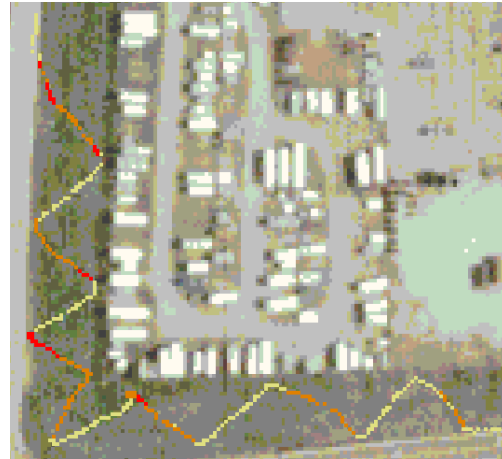
It was anticipated that the results from this scenario would not be as significant as the previous two. The slope leading up to the fence may cause difficulty for the survey member pushing or pulling the cart. This difficulty would likely slow the survey team down.

The bounce and bypass scenarios yielded a 19% and 33% reduction in survey time for the WMD-CST and BEEs respectively. The times from without RAT to RAT decreased due to the short distances between the survey points and waypoints and the overall short total distance. This occurred because there weren't long stretches of terrain between points that could cause the survey cart to slow down the RAT team. The WMD-CST survey team pushed the cart up a hill for less than 30 meters, stopped at the point,

pushed the cart back down the hill, stopped at the next point, and rested again before he needed to push the cart back up the hill. This repetitive process of work, rest, minimal work, and rest over an overall relatively short distance caused little fatigue to the survey member.



**Figure 56: WMD-CST bounce and bypass survey**



**Figure 57: BEE bounce and bypass survey with Fluke®**

Most of the BEE surveys with RAT occurred in less time than the WMD-CST surveys because the BEEs never needed to stop at a given point to monitor. The BEEs were continually monitoring and the WMD-CST monitoring individual points. The routes and distances between cones were identical between the WMD-CST surveys and the BEE surveys. As part of the exercise's administrative rules of engagement (ROE), the OC handed the BEE survey member the source and therefore the survey member did not need to stop. In this scenario, we see a significant reduction in the time required for the BEEs to conduct the site characterization with RAT. The survey team's serial cable measured over 10 feet long. This provided the monitoring survey member several feet of

slack enabling the freedom to move a few feet away from the survey cart and not feel constrained by the cart's movements. As the survey member pulling the survey cart up the hill slowed down, the monitoring survey member did not need to slow down and wait. The monitoring survey member was able to continue the preferred rate-of-march due to the long serial cable. Similarly, on the descent down the hill, the monitoring survey member could lag behind as the pulling survey member rolled down the hill at an accelerated rate-of-march.

**Table 16: Bounce and bypass survey data**

	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	16	13	
WMD-CST w/ RAT	13	372	23 (3, 2, 3, 2, and 3 were consecutive)
BEEs w/o RAT	15	14	
BEEs w/ RAT	10	500	0

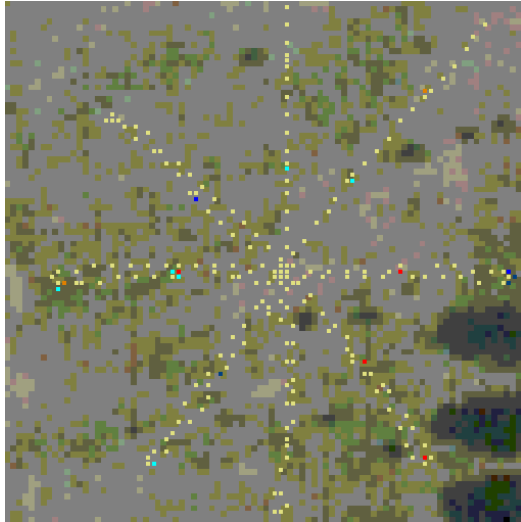
#### **4.6 Radial Survey**

It was anticipated that the results from this scenario would be more revealing than the previous scenario but less revealing than the first two scenarios. The flat hard grass should not present any challenges for the survey member who pushes or pulls the cart. Also, the survey members should experience very little fatigue due to the relatively short

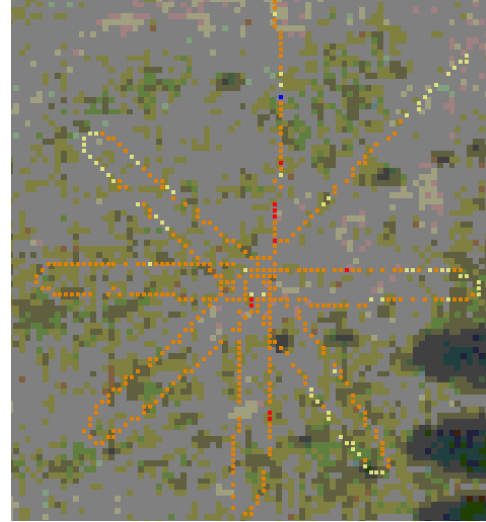
distance. Finally, this scenario presented a new set of conditions relating to GPS signal. This scenario was located in an orchard. However, most of the trees' diameters were less than six inches and should not create problems for the GPS unit's attempt to gain satellite signal.

The radial scenarios resulted in a 7% increase and 54% reduction time in the survey time for the WMD-CST and BEEs, respectively. Again, when evaluating the time required to conduct a site characterization for single points over a small area, the RAT times don't appear very revealing. However, when looking at the total number of points collected, the benefit of RAT becomes obvious. One must consider the amount of time taken at the TOC for a non RAT survey team to produce a product of the same quality as RAT from the DA Form 1971-R. The time would far exceed that of the RAT survey team. Specifically, the operations team in the TOC would take the information on the DA Form 1971-R and produce a product that displayed a visual representation of the locations of the contamination. This could include a piece of imagery with isodose lines on it or with similar colored dots corresponding to the appropriate thresholds. At this point, the weather became an issue for the BEE survey teams without RAT. At times, the recorders had to move their hands and blow on them in an attempt to regain feeling after becoming numb from the cold weather.





**Figure 58: WMD-CST radial survey**



**Figure 59: BEE radial survey with Fluke®**

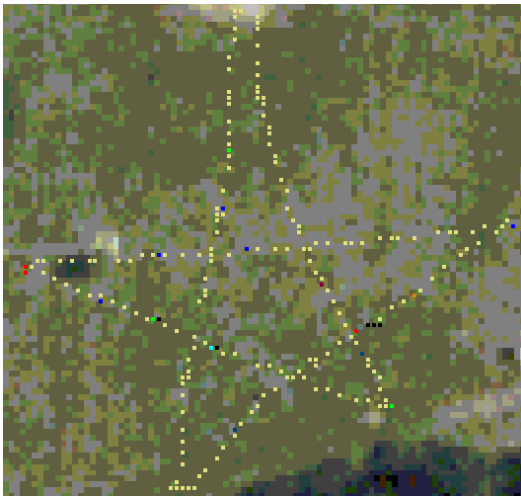
**Table 17: Radial survey data**

	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	15	17	
WMD-CST w/ RAT	16	477	36 (7, 2, 2, 8, and 3 were consecutive)
BEEs w/o RAT	24	33	
BEEs w/ RAT	11	591	0

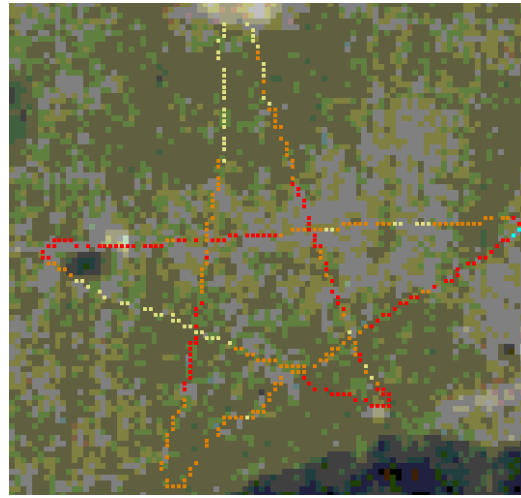
## 4.7 Star Survey

It was anticipated that the results from this scenario would be less revealing than the first two scenarios. Due to the relatively short overall distance coupled with the challenges created by the two hills and the thick grass, the survey teams pushing or pulling the cart would not experience as much time benefit using RAT.

The star survey resulted in 11% and 64% reduction in the survey time for the WMD-CST and BEEs, respectively. This significant reduction in time displays the importance of using RAT in unrestrictive terrain. The terrain on this survey area only contained two small hills and no trees.



**Figure 60: WMD-CST star survey**



**Figure 61: BEE star survey with Fluke®**

**Table 18: Star survey data**

	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	19	25	
WMD-CST w/ RAT	17	501	14 (6 and 2 were consecutive)
BEEs w/o RAT	22	29	
BEEs w/ RAT	8	410	0

#### **4.8 Cloverleaf Survey**

Although not a very long course, the hills of the first, third, and fourth loops presented a challenge for the survey teams pushing and pulling the survey cart.

The cloverleaf scenarios yielded a 17% and 66% reduction in survey time for the WMD-CST and BEEs respectively. This scenario contained four loops of varying difficulty. Loop number one, located on the top of Figures 62 and 63, began within ten meters of the building, traveled across short hard grass, went down a curb, crossed a two lane road, went up a curb, climbed the hill from the bounce and bypass scenario, skirted the fence-line from the bounce and bypass scenario, descended down the hill from the bounce and bypass scenario to a mud puddle, went down a curb, crossed the same two lane road, went up a curb, and traveled back across the short hard grass. Loop number two, located on the left of the images, began within five meters of the smoke stack, traveled along short hard grass, and completed upon arriving within five meters of the building. Loop number three, located at the bottom of the images, descended down a steep hill within five meters of the large building, traveled across level pavement between

the building and 15 foot high and 20 foot long metal containers, continued onto thick soft grass circling around the recycling and disposal building, dropped down a curb, crossed a two lane driveway, climbed up curb, and climbed a freshly seeded less steep hill covered with netting. Loop number four, located at the right of the images, traveled down the freshly seeded less steep hill covered with netting, dropped down the curb, crossed the two lane driveway, climbed up a curb, climbed a steep grassy hard hill, skirted the hill's crest, descended down the steep grassy hard hill, dropped down the curb, and stopped after traveling approximately ten meters on the paved parking lot.



**Figure 62: WMD-CST cloverleaf survey**



**Figure 63: BEE cloverleaf survey with Fluke®**

**Table 19: Cloverleaf survey data**

	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>
WMD-CST w/o RAT	23	28	
WMD-CST w/ RAT	19	590	43 (2, 9, 2, 2, 7, 2, 3, and 2 were consecutive)
BEEs w/o RAT	41	36	
BEEs w/ RAT	14	701	37 (2, 2, 3, 4, 11, 6, 3, and 2 were consecutive)

It is expected that the results from loop number one would be similar to those of the other scenarios with hills. The zigzag scenario times increased with RAT and the bounce and bypass times decreased with RAT. However, loop number one of the cloverleaf scenario shared the same terrain as the bounce and bypass scenario. Therefore, we would expect the results of loop number one to match similarly to the bounce and bypass scenario. However, the results from loop number one reveal that the WMD-CST time actually increased when they switched from with-out RAT to with RAT. The with-out RAT Survey Team took six minutes to arrive at the first point of loop two, point H. The with RAT Survey Team took 6.11 minutes to arrive at point H. These results support the data from the zigzag scenario. It's worth noting that one of the survey members during the RAT cloverleaf scenario also was on the RAT survey team for the zigzag and radial scenarios. This survey member usually pushed the cart. Also, the WMD-CST

survey team's times increased when changing from without RAT to with RAT during only two scenarios. These scenarios included the zigzag and the radial scenarios.

Therefore, we may attribute the results of loop number one to the extra caution taken by a specific survey member.

Loop number one results for the BEEs matched our expected results. The BEEs took significantly less time conducting the survey on loop one when they switched from with-out RAT to with RAT. Based on their arrival time to point H, the first point of loop two, the BEEs survey team with RAT reduced their time from 15 minutes to 3.95 minutes by 74%.

**Table 20: Cloverleaf scenario loop number one**

Cone letter	start	A	B	C	D	E	F	G
WMD-CST w/o RAT time between points (minutes)		0	1	1	1	1	0	1
WMD-CST w/o RAT total elapsed time (minutes)		0	1	2	3	4	4	5
WMD-CST RAT survey point	1	18	46	73	92	110	144	168
WMD-CST w/ RAT time between points (minutes)		0.75	0.95	0.95	0.38	0.76	1.08	0.87
WMD-CST w/ RAT total elapsed time (minutes)		0.75	1.7	2.65	3.03	3.79	4.87	5.74
BEEs w/o RAT time between points (minutes)		0	2	2	2	1	3	2
BEEs w/o RAT total elapsed time (minutes)		0	2	4	6	7	10	12

BEEs RAT survey point	1							
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The WMD-CST survey times, when switching from without RAT to with RAT, decreased for the star survey and slightly increased for the radial survey. Therefore, it's not surprising that the survey time for the WMD-CST survey team with RAT decreased for loop two of the cloverleaf scenario. The times from point H to the first point of loop three, point O, decreased from six minutes to 4.62 minutes creating a 23% time reduction. The BEEs survey times decreased from nine minutes to 2.95 minutes creating a 67% time reduction.

**Table 21: Cloverleaf scenario loop number two**

Cone letter	H	I	J	K	L	M	N
WMD-CST w/o RAT time between points (minutes)	1	1	1	0	1	1	1
WMD-CST w/o RAT total elapsed time (minutes)	6	7	8	8	9	10	11
WMD-CST RAT survey point	186	202	216	230	246	269	283
WMD-CST w/ RAT time between points (minutes)	0.37	0.72	0.28	0.68	0.32	0.86	0.68
WMD-CST w/ RAT total elapsed time (minutes)	6.11	6.83	7.11	7.79	8.11	8.97	9.65
BEEs w/o RAT time between points (minutes)	3	1	2	0	1	2	2
BEEs w/o RAT total elapsed time (minutes)	15	16	18	18	19	21	23

BEEs RAT survey point	207						
BEEs w/ RAT total elapsed time (minutes)	3.95						

The WMD-CST times for loop three decreased when the survey teams switched from with-out RAT to with RAT. From point O to the first point of loop four, point V, the times decreased from six minutes to 4.9 minutes creating an 18% time reduction.

**Table 22: Cloverleaf scenario loop number three**

Cone letter	O	P	Q	R	S	T	U
WMD-CST w/o RAT time between points (minutes)	1	1	1	1	1	0	1
WMD-CST w/o RAT total elapsed time (minutes)	12	13	14	15	16	16	17
WMD-CST RAT survey point	317	334	357	375	391	411	435
WMD-CST w/ RAT time between points (minutes)	1.08	0.34	0.86	0.76	0.32	0.8	0.88
WMD-CST w/ RAT total elapsed time (minutes)	10.73	11.07	11.93	12.69	13.01	13.81	14.69
BEEs w/o RAT time between points (minutes)	1	1	2	1	1	1	2
BEEs w/o RAT total elapsed time (minutes)	24	25	27	28	29	30	32
BEEs RAT survey point	357	389			439		
BEEs w/ RAT total elapsed time (minutes)	6.9	7.26			8.25		



For the BEE survey teams, the combined times for loop three and four, measured from point O to stop point, decreased from 17 minutes to 6.45 minutes yielding a 62% time reduction. The WMD-CST times for loop four decreased when the survey teams switched from with-out RAT to with RAT. From point V to the stop point, the times decreased from five minutes to 4.13 minutes creating a 17% time reduction.

**Table 23: Cloverleaf scenario loop number four**

Cone letter	V	W	X	Y	Z	AA	BB	stop
WMD-CST w/o RAT time between points (minutes)	1	1	0	1	1	1	1	0
WMD-CST w/o RAT total elapsed time (minutes)	18	19	19	20	21	22	23	23
WMD-CST RAT survey point	462	479	493	519	536	553	577	614
WMD-CST w/ RAT time between points (minutes)	0.94	0.34	0.67	0.53	0.74	0.74	0.47	0.64
WMD-CST w/ RAT total elapsed time (minutes)	15.63	15.97	16.64	17.17	17.91	18.65	19.12	19.76
BEEs w/o RAT time between points (minutes)	2	1	1	0	2	0	2	1
BEEs w/o RAT total elapsed time (minutes)	34	35	36	36	38	38	40	41
BEEs RAT survey point								701
BEEs w/ RAT total elapsed time (minutes)								13.35

As a result of this data, it is recommended that first responders use RAT in outdoor non-wooded environments with reliable GPS coverage. In addition, additional instruments, such as the SAM940, should be interfaced with RAT.

#### **4.9 Summary and Significance of Results**

The results from this research present a potential application for the United States Air Force's (USAF's) BEE career field and AFRAT. RAT will provide a cost effective system for the AFRAT Commander to use in an attempt to gain an accurate COP. The intuitiveness of the software allows trainers to quickly train personnel on its operation. Furthermore, the multitude of devices compatible with RAT makes it a strong program to share data among many agencies. Therefore, not only does RAT serve as a useful tool for the DOD, it also could serve as a useful tool when the DOD operates with other agencies. This would provide a solution to the difficulties that agencies face in attempting to establish interoperability in a CM response. As a result, the RAT system reduces manpower required to establish specific mR/hr zones and site characterizations.

Table 13 displays the percent change in time for each scenario when the survey teams changed from surveying without RAT to with RAT. The times increased for only two of the 12 iterations and were primarily due to difficulty maneuvering the survey cart. However, the cart issues could be eliminated by wearing backpacks or tablet PCs with a harness.

## 5. Conclusion

### 5.1 Summary

RAT averaged a 29.9% decrease in survey time and a 24.4 times increase (24,400%) in the number of data points collected. Tables K1 and K2 (Appendix K) display these calculations.

### 5.2 Future Research

Future research would involve integrating the SAM940 because most survey teams will use a gamma spectroscopy detector. The SAM940 has a serial port and could easily be incorporated into RAT. Other research would involve establishing a network with such devices as a wireless air card and creating a more mobile means through the application of devices such as a heads-up display monocle. Additionally, further research could look closely at what specific human errors do the survey members make while transcribing the data onto the DA Form 1971-R. For instance, for some of the points in the lane scenario, the survey member transmitted over the FM radio units of  $\mu\text{R/hr}$  vice  $\text{mR/hr}$ . Further analysis could be conducted by taking the given data from this research and using an operations team to produce a database from the DA Form 1971-R and create a plot or contour of the results. That way the research would compare how long it took an operations team to prepare a product similar to the products produced by RAT. With that standardization, the time benefit of RAT would become much more apparent. Additionally, further research could look at a rigorous statistical evaluation of the data

stored by RAT. Finally, due to the huge amount of sampling points that are taken and stored with RAT, perhaps doctrine, sampling plans, and/or survey TTPs may need to be adjusted. Simply put, future research could address the new considerations based on the increased amount of data collection.

An additional area to explore in future research would include establishing a network with such devices as a wireless air card. This requirement became obvious through the findings in TRADOC Pamphlet 525-7-19. The pamphlet determines that the network must contain the following ten capabilities (Vane, 2009):

1. The network must "...be reliable, redundant, and defended against computer network attack."
2. The network must direct meaningful, accurate, timely, and properly formatted information in order for the commander to gain SU.
3. Terrain and location must not hinder communication.
4. The network must establish and maintain interoperability beyond the DOD to CF and industry.
5. The network must provide Soldiers and teams with a shared COP while preventing an overwhelming amount of complex and excessive information.
6. The network must allow the echelons above the surveyors to provide digitized feedback back down to the surveyors.
7. The network must facilitate near real time reach-back.
8. The network must "...provide access to the global information grid (GIG)."
9. The network's systems must "...not present a single point of failure."
10. Networked sensor inputs must "...automatically disseminate critical, time sensitive CBRN hazard warnings..." in order to allow soldiers near the hazard to don PPE and/or maneuver away from the hazard.

Minor corrections to the RAT source code include eliminating all of the warning messages that occur when compiling RAT. Another modification to RAT could include creating a dashboard like screen to prompt the user when devices are plugged in.

Furthermore, as the number of devices compatible with RAT expands it may become helpful for RAT to search first only for those devices that a specific team uses. This

would eliminate the potential for RAT taking a significant amount of time searching through a long list of devices and instead go first to the devices that the user frequently utilizes.

Finally, efforts should focus on making RAT as mobile and portable as possible. This research addressed the one potential disadvantage in the added time that a survey may take due to traveling across restrictive terrain with a survey cart. This slight disadvantage could quickly be overcome with a mobile means to use RAT.

Other potential difficulties include operating in locations with poor GPS coverage and the configuration utilized in these experiments consisting of non-rugged and non-weatherproof wires. However, it must be understood that RAT can be used in buildings in either real time or as a host. Finally, one of the significant facts surrounding RAT is that it can be used to integrate with new and emerging technologies in order to provide real-time situational awareness. As long as a device has a serial port, it can most likely be integrated with RAT.

## Appendix A: Radiation Health Effects

**Table A1: Dose Guidelines and Turn-back Exposure Rates (“Radiation Event Medical Management,” 2009)**

<b>Total Dose Equivalent</b>	<b>Turn-Back Exposure Rates</b>	<b>Activities</b>
5 rem	Follow radiation safety instructions	Emergency worker dose limit
10 rem	10 R/hr	Non-lifesaving activities (e.g., protect critical infrastructure)
50 rem	200 R/hr  Use extreme caution	Lifesaving activities

**Table A2: Radiation Exposure Status (RES) and degree of risk (Sullivan and Mundy, 1994)**

<b>RES Category</b>	<b>Total Past Cumulative Dose Equivalent (cGy)</b>	<b>Possible exposure criteria, for a single operation that will not result in exceeding the dose criteria for the stated degree of risk (cGy)</b>
RES-0	0	Negligible risk: $\leq 50$
		Moderate risk: $\leq 70$
		Emergency risk: $\leq 150$
RES-1	$0 < \text{dose equivalent} \leq 70$	Negligible risk: $\leq 10$
		Moderate risk: $\leq 30$
		Emergency risk: $\leq 110$
RES-2	$70 < \text{dose equivalent} \leq 150$	Any further exposure is considered to exceed a negligible or moderate risk.
		Emergency risk: $\leq 40$
RES-3	$\text{dose equivalent} > 150$	Any further exposure will exceed the emergency risk.

**Table A3: “Effects of radiation exposure on combat personnel” (Sullivan and Mundy, 1994)**

<b>Dose Equivalent Range (cGy)</b>	<b>Initial Symptoms</b>	<b>Duration</b>	<b>Final Disposition</b>
0-70	Possible slight headache and nausea. Vomiting in up to 5% of personnel.	6-12 hours	Duty
70-150	Mild nausea vomiting in 5-30% of personnel. Vomiting in up to 5% of personnel in upper range.	2-20 hours	Duty: no deaths.
150-300	Mild to moderate nausea and vomiting in 20-70% of personnel. Mild to moderate fatigue and weakness in 25-60% of personnel.	2-48 hours	Duty: < 5% deaths at low end of range; death may occur in 10% of personnel.



## Appendix B: ADM300 Data Strings

**Table B1: ADM300 sample string (Kulkarni, Hall and O'Brien, 2003)**

<b>nnaRRRSE_DDSE_UUUSE_RDBG.IxxxxxAxxxx#_AAASE_NN]</b>
39a132+0 040-1 113+0 R..L.I00U1BA5509 00000 40]
40a133+0 041-1 138+0 R..L.I00U1QA550: 00000 57]
41a133+0 042-1 149+0 R..L.I00U1WA5501 600-1 44]
42a133+0 042-1 113+0 R..L.I00U1CA5502 100+2 5D]
43a132+0 043-1 124+0 R..L.I00U1HA5503 00000 4A]
45a016-1 050-1 037-1 R..L.I00U03A5507 00000 34]
46a016-1 050-1 000-1 R..L.I00U00A5508 10000 3F]
50a015-1 050-1 024-1 R..L.I00U02A5502 100+2 2D]
52a015-1 050-1 012-1 ...L.I00g01A5504 00000 79]
56a013-1 050-1 000-1 ...L.I00U00A550: 00000 45]
57a013-1 050-1 000-1 ...L.I00U00A5501 600-1 55]
59a013-1 000-1 000-1 ...L.I00e00A5503 00000 76]

This table displays 12 separate strings of data as they transmit from the ADM300's serial port.

**Table B2: ADM300 sample string (Grimaila, 2009)**

<b>nnaRRRSE_DDSE_UUUSE_RDBG.IxxxxxAxxxx#_AAASE_NN]</b>
39a017-1 035-1 044-1 ...L.I00U01A5509 00000 49]
40a017-1 035-1 042-1 ...L.I00U01A550: 00000 42]
41a017-1 035-1 042-1 ...L.I00U01A5501 600-1 52]
42a020-1 035-1 090-1 ...L.I00U02A5502 100+2 58]
43a021-1 035-1 000-1 ...L.I00U00A5503 40730 4A]
44a021-1 035-1 044-1 ...L.I00U01A5504 00000 4B]
45a020-1 035-1 000-1 ...L.I00U00A5507 00000 49]
46a019-1 035-1 000-1 ...L.I00U00A5508 00000 4F]
47a018-1 035-1 000-1 ...L.I00U00A5509 00000 4E]
48a016-1 035-1 000-1 ...L.I00U00A550: 00000 4C]
49a016-1 035-1 042-1 ...L.I00U01A5501 600-1 5B]
50a018-1 035-1 042-1 ...L.I00U01A5502 100+2 5C]
51a020-1 035-1 128-1 ...L.I00U03A5503 40730 40]
52a021-1 035-1 000-1 ...L.I00U00A5504 00000 4D]
53a020-1 035-1 000-1 ...L.I00U00A5507 00000 4E]
54a020-1 035-1 000-1 ...L.I00U00A5508 00000 46]
55a020-1 035-1 000-1 ...L.I00U00A5509 00000 46]
56a019-1 035-1 000-1 ...L.I00U00A550: 00000 4C]
57a017-1 035-1 000-1 ...L.I00U00A5501 600-1 52]
58a018-1 035-1 000-1 ...L.I00U00A5502 100+2 53]
59a017-1 035-1 000-1 ...L.I00U00A5503 40730 44]
60a016-1 035-1 044-1 ...L.I00U01A5504 00000 49]
61a016-1 035-1 000-1 ...L.I00U00A5507 00000 4A]

**Table B3: Translation of strings from Tables B1 and B2**

String	Line #	ADM300?	Dose rate mR/h	Dose mR	Rate alarm? / low-range GM?	Probes attached? / alarms set?	Alarm set-point	Checksum good?
39a132+0 040-1 113+0 R..L.I00U1BA5509 00000 40]	39	Y	1.32	0.04	yes, no	no, no		Y
40a133+0 041-1 138+0 R..L.I00U1QA550: 00000 57]	40	Y	1.33	0.041	yes, no	no, yes		Y
41a133+0 042-1 149+0 R..L.I00U1WA5501 600-1 44]	41	Y	1.33	0.042	yes, no	no, yes rate alarm =	.6 mR/h	Y
42a133+0 042-1 113+0 R..L.I00U1CA5502 100+2 5D]	42	Y	1.33	0.042	yes, no	no, yes dose alarm =	100 mR	Y
43a132+0 043-1 124+0 R..L.I00U1HA5503 00000 4A]	43	Y	1.32	0.043	yes, no	no, no		Y
45a016-1 050-1 037-1 R..L.I00U03A5507 00000 34]	45	Y	.016	0.05	yes, no	no, no		Y
46a016-1 050-1 000-1 R..L.I00U00A5508 10000 3F]	46	Y	.016	0.05	yes, no	no, no		Y
50a015-1 050-1 024-1	50	Y	.015	0.05	yes,	no, no	100	Y

R..L.I00U02A5502 100+2 2D]					no		mR	
52a015-1 050-1 012-1 ...L.I00g01A5504 00000 79]	52	Y	.015	0.05	no, yes	no, no		Y
56a013-1 050-1 000-1 ...L.I00U00A550: 00000 45]	56	Y	.013	0.05	no, yes	no, yes		Y
57a013-1 050-1 000-1 ...L.I00U00A5501 600-1 55]	57	Y	.013	0.05	no, yes	no, yes rate alarm =	.6 mR/h	Y
59a013-1 000-1 000-1 ...L.I00e00A5503 00000 76]	59	Y	.013	0	no, yes	no, no		Y
39a017-1 035-1 044-1 ...L.I00U01A5509 00000 49]	39	Y	.017	0.035	no, yes	no, no		Y
40a017-1 035-1 042-1 ...L.I00U01A550: 00000 42]	40	Y	.017	0.035	no, yes	no, yes		Y
41a017-1 035-1 042-1 ...L.I00U01A5501 600-1 52]	41	Y	.017	0.035	no, yes	no, yes rate alarm =	.6 mR/h	Y
42a020-1 035-1 090-1 ...L.I00U02A5502 100+2 58]	42	Y	.02	0.035	no, yes	no, yes dose alarm =	100 mR	Y
43a021-1 035-1 000-1 ...L.I00U00A5503 40730 4A]	43	Y	.021	0.035	no, yes	no, no	40730	Y
44a021-1 035-1 044-1 ...L.I00U01A5504 00000 4B]	44	Y	.021	0.035	no, yes	no, no		Y
45a020-1 035-1 000-1 ...L.I00U00A5507 00000 49]	45	Y	.020	0.035	no, yes	no, no		Y

46a019-1 035-1 000-1 ...L.I00U00A5508 00000 4F]	46	Y	.019	0.035	no, yes	no, no		Y
47a018-1 035-1 000-1 ...L.I00U00A5509 00000 4E]	47	Y	.018	0.035	no, yes	no, no		Y
48a016-1 035-1 000-1 ...L.I00U00A550: 00000 4C]	48	Y	.016	0.035	no, yes	no, yes		Y
49a016-1 035-1 042-1 ...L.I00U01A5501 600-1 5B]	49	Y	.016	0.035	no, yes	no, yes rate alarm =	.6 mR/h	Y
50a018-1 035-1 042-1 ...L.I00U01A5502 100+2 5C]	50	Y	.018	0.035	no, yes	no, yes dose alarm =	100 mR	Y
51a020-1 035-1 128-1 ...L.I00U03A5503 40730 40]	51	Y	.020	0.035	no, yes	no, no	40730	Y
52a021-1 035-1 000-1 ...L.I00U00A5504 00000 4D]	52	Y	.021	0.035	no, yes	no, no		Y
53a020-1 035-1 000-1 ...L.I00U00A5507 00000 4E]	53	Y	.020	0.035	no, yes	no, no		Y
54a020-1 035-1 000-1 ...L.I00U00A5508 00000 46]	54	Y	.020	0.035	no, yes	no, no		Y
55a020-1 035-1 000-1 ...L.I00U00A5509 00000 46]	55	Y	.020	0.035	no, yes	no, no		Y
56a019-1 035-1 000-1 ...L.I00U00A550: 00000 4C]	56	Y	.019	0.035	no, yes	no, yes		Y
57a017-1 035-1 000-1 ...L.I00U00A5501 600-1 52]	57	Y	.017	0.035	no, yes	no, yes rate alarm	.6 mR/h	Y

						=		
58a018-1 035-1 000-1 ...L.I00U00A5502 100+2 53]	58	Y	.018	0.035	no, yes	no, yes dose alarm =	100 R	Y
59a017-1 035-1 000-1 ...L.I00U00A5503 40730 44]	59	Y	.017	0.035	no, yes	no, no	40730	Y
60a016-1 035-1 044-1 ...L.I00U01A5504 00000 49]	60	Y	.016	0.035	no, yes	no, no		Y
61a016-1 035-1 000-1 ...L.I00U00A5507 00000 4A]	61	Y	.016	0.035	no, yes	no, no		Y

## Appendix C: Testing Checksum

ASCII	Hex	Binary		
<cr>	0D	00001101		
<lf>	0A	00001010		
		00000111	7	
7	37	00110111	37	
		00110000	30	
4	34	00110100	34	
		00000100	4	
a	61	01100001	61	
		01100101	65	
0	30	00110000	30	
		01010101	55	
5	35	00110101	35	
		01100000	60	
6	36	00110110	36	
		01010110	56	
-	2D	00101101	2D	
		01111011	7B	
1	31	00110001	31	
		01001010	4A	
	20	00100000	20	
		01101010	6A	
6	36	00110110	36	

		01011100	5C	
9	39	00111001	39	
		01100101	65	
1	31	00110001	31	
		01010100	54	
-	2D	00101101	2D	
		01111001	79	
1	31	00110001	31	
		01001000	48	
	20	00100000	20	
		01101000	68	
0	30	00110000	30	
		01011000	58	
4	34	00110100	34	
		01101100	6C	
2	32	00110010	32	
		01011110	5E	
-	2D	00101101	2D	
		01110011	73	
1	31	00110001	31	
		01000010	42	
	20	00100000	20	
		01100010	62	
R	52	01010010	52	
		00110000	30	



.	2E	00101110	2E	
		00011110	1E	
.	2E	00101110	2E	
		00110000	30	
L	4C	01001100	4C	
		01111100	7C	
.	2E	00101110	2E	
		01010010	52	
I	49	01001001	49	
		00011011	1B	
0	30	00110000	30	
		00101011	2B	
0	30	00110000	30	
		00011011	1B	
U	55	01010101	55	
		01001110	4E	
0	30	00110000	30	
		01111110	7E	
1	31	00110001	31	
		01001111	4F	
A	41	01000001	41	
		00001110	E	
5	35	00110101	35	
		00111011	3B	
5	35	00110101	35	

		00001110	E	
0	30	00110000	30	
		00111110	3E	
8	38	00111000	38	
		00000110	6	
	20	00100000	20	
		00100110	26	
0	30	00110000	30	
		00010110	16	
0	30	00110000	30	
		00100110	26	
0	30	00110000	30	
		00010110	16	
0	30	00110000	30	
		00100110	26	
0	30	00110000	30	
		00010110	16	
	20	00100000	20	
		00110110	<b>36</b>	Check Sum matches
3	33	00110011	33	
		00000101	5	
6	36	00110110	36	
		00110011	33	
]	5D	01011101	5D	
		01101110	6E	

## Appendix D: A Partial list of the changes made to the RAT Source Code

1. C:\RAT\bin
  - a. Open **RATConfig.mdb**
    - i. Edit Devises: Table
      1. Add row:
        - a. Device: 12
        - b. Description: Grey and Black ADM-300
        - c. Manufacturer: Canberra
        - d. Model: ADM-300
        - e. Check boxes: continuous collect, configure, detect, allow multiple, and allow same
        - f. End Transmission = 13
        - g. MissedComThr = 12
      - ii. Edit Categorized Devices: Table
        1. Add row:
          - a. Category: 0
          - b. Devise: 12
      - iii. Exit
    - b. **RatTemplate.mdb**
      - i. Copy Inovision Table to Canberra Table
      - c. dbTemp.mdb
  2. Building RAT requires the file  
C:\ProgramFiles\CommonFiles\MergedModules\vfpoledb.msm located at  
<http://www.microsoft.com/downloads/details.aspx?FamilyId=E1A87D8F-2D58-491F-A0FA-95A3289C5FD4&displaylang=en>
  3. Locations that we need to look at closely:
    - a. File: DeviceDetect.vb
      - i. Routine: DetectionThread()
    - b. File: **CInovision.vb**
      - i. Function: Detect
      - ii. Cloned CInovision.vb as CCanberra.vb
        1. Change name of Class from CInovision to CCanberra
        2. Build
          - a. Files of interest
            - i. **frmDeviceInfo.vb**
              1. Copy (Ln947 to Ln964 for 451P ) and add Elseif (for ADM300) (If, ElseIf, ElseIf, Else, End If) Deleted mSv/hr for ADM300.
            - ii. Atltrace.h
              1. Nothing of interest

**iii. DeviceForm.vb**

1. Copy Ln438 to Ln 460 and paste below
2. Replace “Fluke Victoreen” with “Canberra”
3. Replace xxx with CCanberra
4. Replace frmInovision with frmCanberra
5. Create frmCanberra.vb similar to frmInovision.vb (can’t simply copy)
  - a. Draw same type of form
  - b. Copy code from frmInovision.vb
  - c. Replace all “Inovision” with “Canberra”

**iv. DeviceDetect.vb**

1. Insert at Ln63 the copied “Fluke Victoreen 451P” lines that precede this location. Replace with “Canberra ADM-300”
2. Insert at Ln149 the copied lines that precede this location. Replace with “Canberra ADM-300”

**v. DeviceCollection.vb**

1. Insert at Ln311 the copied lines that precede this location (Ln 301-310). Replace with “Canberra ADM-300”

**vi. frmConnectUpdate.vb**

- 1.

**vii. frmRAT.vb**

1. At Ln6101 leave “and”
  - a. This is “Error 91 BuildCommPort”
2. At Ln2091, add “Canberra”
3. At Ln4158, add “Canberra”
4. Insert at Ln5616 the copied “Fluke Victoreen 451P” lines that precede this location. Replace with “Canberra ADM-300”
5. Insert at Ln5688 the copied “Fluke Victoreen 451P” lines that precede this location. Replace with “Canberra ADM-300”
6. Insert at Ln5800 the copied “Fluke Victoreen 451P” lines that precede this location. Replace with “Canberra ADM-300”

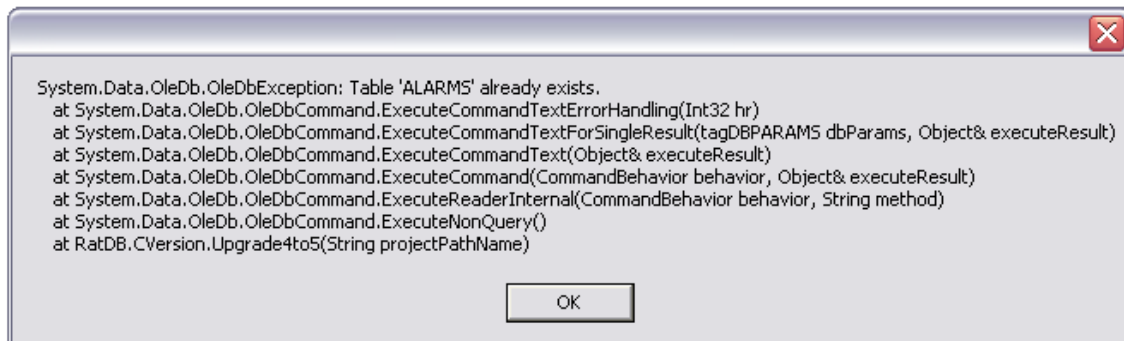


## Appendix E: A complete list of the problems encountered with this version of RAT

1. When I try to open an old project.



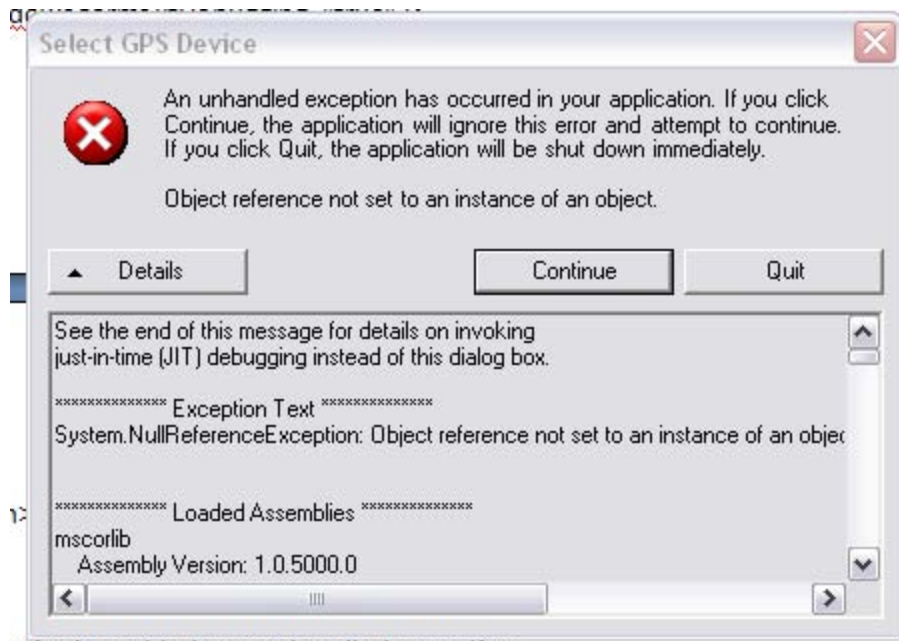
“Yes”



“OK” and nothing happens. RAT doesn’t crash, nothing loads.

I had this same issue with “Original RAT” (the version I downloaded from epa.gov).

2. This happened once when I tried connecting GPS.



See the end of this message for details on invoking  
just-in-time (JIT) debugging instead of this dialog box.

\*\*\*\*\* Exception Text \*\*\*\*\*

System.NullReferenceException: Object reference not set to an instance of an object.

\*\*\*\*\* Loaded Assemblies \*\*\*\*\*

mscorlib

Assembly Version: 1.0.5000.0

Win32 Version: 1.1.4322.573

CodeBase: file:///c:/windows/microsoft.net/framework/v1.1.4322/mscorlib.dll

-----  
RAT

Assembly Version: 1.4.3590.23529

Win32 Version: 1.4.3590.23529

CodeBase: file:///C:/RAT/RAT.exe

-----  
System.Windows.Forms

Assembly Version: 1.0.5000.0

Win32 Version: 1.1.4322.573

CodeBase:

file:///c:/windows/assembly/gac/system.windows.forms/1.0.5000.0\_\_b77a5c561934e089/  
system.windows.forms.dll

-----  
System

Assembly Version: 1.0.5000.0

Win32 Version: 1.1.4322.573

CodeBase:  
file:///c:/windows/assembly/gac/system/1.0.5000.0\_\_b77a5c561934e089/system.dll  
-----  
Microsoft.VisualBasic  
Assembly Version: 7.0.5000.0  
Win32 Version: 7.10.3052.4  
CodeBase:  
file:///c:/windows/assembly/gac/microsoft.visualbasic/7.0.5000.0\_\_b03f5f7f11d50a3a/microsoft.visualbasic.dll  
-----  
System.Drawing  
Assembly Version: 1.0.5000.0  
Win32 Version: 1.1.4322.573  
CodeBase:  
file:///c:/windows/assembly/gac/system.drawing/1.0.5000.0\_\_b03f5f7f11d50a3a/system.drawing.dll  
-----  
Microsoft.VisualBasic.Compatibility.Data  
Assembly Version: 7.0.5000.0  
Win32 Version: 7.10.3077  
CodeBase: <file:///C:/RAT/Microsoft.VisualBasic.Compatibility.Data.DLL>  
-----  
MSDATASRC  
Assembly Version: 7.0.3300.0  
Win32 Version: 7.00.9466  
CodeBase:  
file:///c:/windows/assembly/gac/msdatasrc/7.0.3300.0\_\_b03f5f7f11d50a3a/msdatasrc.dll  
-----  
ADODB  
Assembly Version: 7.0.3300.0  
Win32 Version: 7.10.2346  
CodeBase:  
[file:///c:/windows/assembly/gac/adodb/7.0.3300.0\\_\\_b03f5f7f11d50a3a/adodb.dll](file:///c:/windows/assembly/gac/adodb/7.0.3300.0__b03f5f7f11d50a3a/adodb.dll)  
-----  
AxInterop.MSComDlg  
Assembly Version: 1.2.0.0  
Win32 Version: 1.2.0.0  
CodeBase: file:///C:/RAT/AxInterop.MSComDlg.DLL  
-----  
System.Data  
Assembly Version: 1.0.5000.0  
Win32 Version: 1.1.4322.573



CodeBase:  
file:///c:/windows/assembly/gac/system.data/1.0.5000.0\_\_b77a5c561934e089/system.data.dll

---

AxInterop.RatUMLib  
Assembly Version: 1.0.0.0  
Win32 Version: 1.0.0.0  
CodeBase: file:///C:/RAT/AxInterop.RatUMLib.DLL

---

Microsoft.VisualBasic.Compatibility  
Assembly Version: 7.0.5000.0  
Win32 Version: 7.10.3077  
CodeBase: file:///C:/RAT/Microsoft.VisualBasic.Compatibility.DLL

---

RatUM  
Assembly Version: 0.0.0.0  
Win32 Version: 1, 0, 1, 5  
CodeBase: file:///C:/RAT/RatUM.ocx

---

Interop.RatUMLib  
Assembly Version: 1.0.0.0  
Win32 Version: 1.0.0.0  
CodeBase: file:///C:/RAT/Interop.RatUMLib.DLL

---

Accessibility  
Assembly Version: 1.0.5000.0  
Win32 Version: 1.1.4322.573  
CodeBase:  
file:///c:/windows/assembly/gac/accessibility/1.0.5000.0\_\_b03f5f7f11d50a3a/accessibility.dll

---

Interop.MSComDlg  
Assembly Version: 1.2.0.0  
Win32 Version: 1.2.0.0  
CodeBase: file:///C:/RAT/Interop.MSComDlg.DLL

---

CustomMarshalers  
Assembly Version: 1.0.5000.0  
Win32 Version: 1.1.4322.573  
CodeBase:  
file:///c:/windows/assembly/gac/custommarshalers/1.0.5000.0\_\_b03f5f7f11d50a3a/custommarshalers.dll

---

---

#### RatDB

Assembly Version: 1.0.3590.24250

Win32 Version: 1.0.3590.24250

CodeBase: file:///C:/RAT/RatDB.DLL

#### Interop.Scripting

Assembly Version: 1.0.0.0

Win32 Version: 1.0.0.0

CodeBase: file:///C:/RAT/Interop.Scripting.DLL

#### \*\*\*\*\* JIT Debugging \*\*\*\*\*

To enable just in time (JIT) debugging, the config file for this application or machine (machine.config) must have the jitDebugging value set in the system.windows.forms section. The application must also be compiled with debugging enabled.

For example:

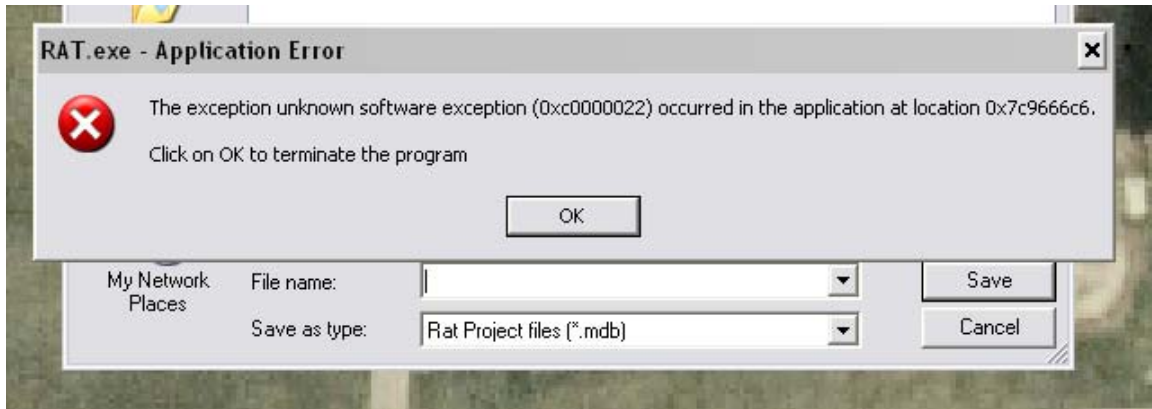
<configuration>

<system.windows.forms jitDebugging="true" />

</configuration>

When JIT debugging is enabled, any unhandled exception will be sent to the JIT debugger registered on the machine rather than being handled by this dialog.

3. The same issue from last time occurred when I started a second project without stopping the GPS. On the third time, I turned the GPS off, opened a new project, turned the GPS back on, and connected to the GPS. There was no issue.
4. At the end of the scenario, I pushed the center mouse button, and it crashed RAT. I couldn't print screen (IOT to capture what the issue was), because the "send error report" box came up and I couldn't move it.
5. I had some problems connecting the GPS on my second project of the day. The screen on the Trimble® would show the plugs trying to connect to each other. Eventually it connected. However, immediately after I successfully connected to GPS, the following problem occurred when I tried to save the project:

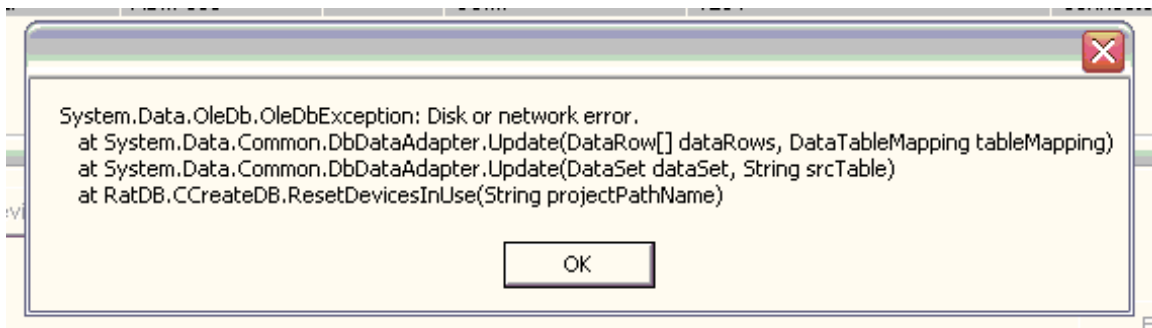


The next time I reconnected to GPS, RAT crashed when I was saving and entering the file name.

Eventually, the GPS connected and everything worked fine. I don't recall doing anything different during the times that it worked without issue.

6. I successfully connected GPS. Then, I successfully connected the ADM-300.

However, this box popped up.



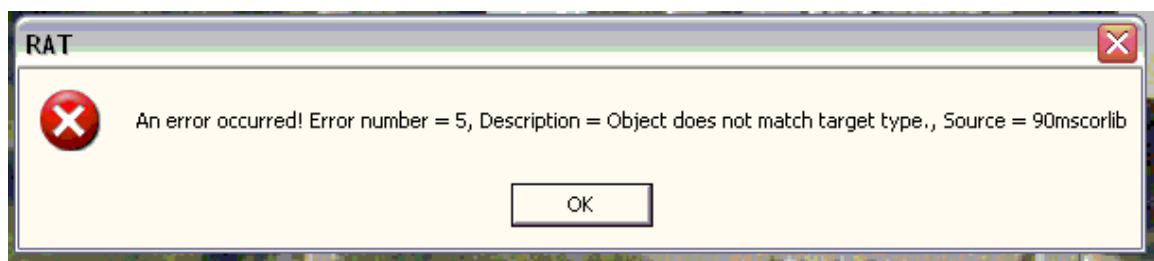
I clicked "OK." RAT didn't crash. It behaved perfectly.

7. On my third project of the day, I successfully connected GPS. Then, I successfully connected the ADM-300. However, when I attempted to "Create/Open File," the following box appeared.



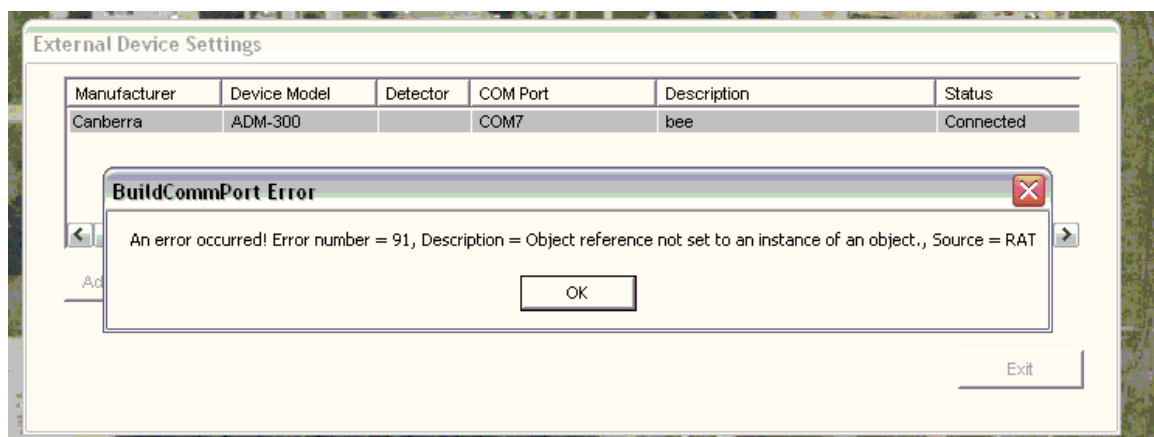
I clicked “close.” RAT crashed. After that, RAT behaved perfectly.

8. The following box popped up while surveying.

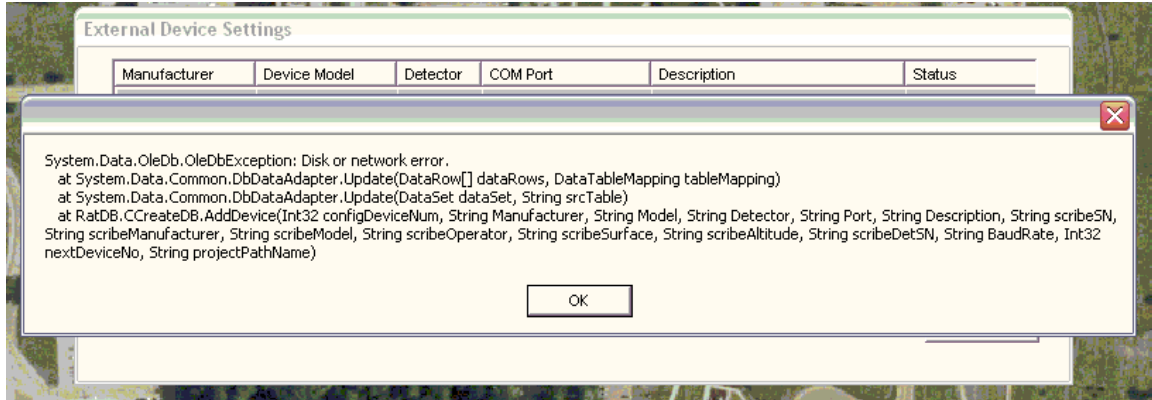


Clicked “OK” and RAT behaved properly.

9. When connecting BEE ADM300 with new cable.



Clicked “OK” and the following popped-up.



Clicked “OK.” Everything was OK, I thought. Status said it was connected, but it wasn’t, because “Create/Open File” was grayed out. I opened the status window and only had data from the GPS. I successfully reconnected the ADM300 a second time and RAT behaved without incident.

## Appendix F: Data integrity test

Date of Project	Number of points sampled
2NOV	516
2NOV	1688
3NOV	133
3NOV	61
5NOV	1077
5NOV	335
5NOV	914
6NOV	165
6NOV	158
6NOV	398
9NOV	123
9NOV	124
9NOV	284
9NOV	598
10NOV	200
10NOV	137
10NOV	585
10NOV	474
13NOV	198
13NOV	235
16NOV	306
16NOV	196
16NOV	225
16NOV	116
20NOV	151
20NOV	245
<b>TOTAL</b>	<b>9642</b>

## Appendix G: Exercise Timelines

**Table G1: WMD-CST Exercise Timeline**

<b>Scenario #</b>	<b>Survey Technique</b>	<b>w/o RAT or w/ RAT</b>	<b>Team</b>	<b>Duration (minutes)</b>	<b>Start time</b>	<b>End time</b>
1A	Modified Lane	w/o RAT	A	45	0700	0745
1B	Modified Lane	w/ RAT	B	30	0745	0815
Detail (collect and set-up sources)			D	30	0815	0845
2A	Modified Zigzag	w/o RAT	C	45	0845	0930
2B	Modified Zigzag	w/ RAT	D	30	0930	1000
Detail (collect and set-up sources)			A	30	1000	1030
3A	Bounce and Bypass	w/o RAT	B	25	1030	1055
3B	Bounce and Bypass	w/ RAT	C	15	1055	1110
Detail (collect and set-up sources)			B	30	1110	1140
4A	Radial	w/o RAT	D	35	1140	1215
4B	Radial	w/ RAT	A	25	1215	1240
Detail (collect and set-up sources)			C	30	1240	1310
5A	Star	w/o RAT	B	30	1310	1340
5B	Star	w/ RAT	C	20	1340	1400
Detail (collect and set-up sources)			A	30	1400	1430

Detail (collect cones from scenarios 1 through 5)			B	45	1430	1515
6A	Cloverleaf	w/o RAT	D	30	1430	1500
6B	Cloverleaf	w/ RAT	A	20	1500	1520
Detail (collect sources and cones from scenario 6)			C	30	1520	1550

**Table G2: BEE Exercise Timeline**

Scenario #	Survey Technique	w/o RAT or w/ RAT	Team	Duration (minutes)	Start time	End time
1A	Modified Lane	w/o RAT	A	60	0700	0800
1B	Modified Lane	w/ RAT	B	60	0800	0900
2A	Modified Zigzag	w/o RAT	C	90	0900	1030
2B	Modified Zigzag	w/ RAT	A	90	1030	1200
Detail (resupply bottles if necessary)			C	60	1030	1130
3A	Bounce and Bypass	w/o RAT	B	30	1200	1230
3B	Bounce and Bypass	w/ RAT	C	30	1230	1300
Detail (resupply bottles if necessary)			B	60	1230	1330
4A	Radial	w/o RAT	A	30	1300	1330
4B	Radial	w/ RAT	B	30	1330	1400
Detail (resupply bottles if necessary)			A	60	1330	1430
5A	Star	w/o RAT	C	30	1400	1430
5B	Star	w/ RAT	A	30	1430	1500



Detail (resupply bottles if necessary)			C	60	1430	1530
Detail (pick-up cones beginning with Scenario #1 and stack on bricks near entrance to Building 470)			A	30	1500	1530
6A	Cloverleaf	w/o RAT	B	60	1500	1600
6B	Cloverleaf	w/ RAT	C	60	1600	1700
Detail (pick-up cones beginning with Scenario #6 and stack on bricks near entrance to Building 470)			B	30	1700	1730

Appendix H: Summary of each WMD-CST scenario

<b>Scenario #</b>	<b>Survey Technique</b>	<b>w/o or w/ RAT</b>	<b>Team Members (A-G)</b>	<b>Duration (minutes)</b>	<b># of points surveyed</b>	<b># of points lost</b>	<b>Start time</b>	<b>End time</b>
1A	Modified Lane	w/o RAT	G, B	31	28		0708	0739
1B	Modified Lane	w/ RAT	A, C	20	614	12 (3 were consecutive)	0748	0808
2A	Modified Zigzag	w/o RAT	E, F	24	24		0826	0850
2B	Modified Zigzag	w/ RAT	D, B	30	888	24 ( 2, 3, 2, 2, and 2 were consecutive)	0910	0940
3A	Bounce and Bypass	w/o RAT	G, C	16	13		0953	1009
3B	Bounce and Bypass	w/ RAT	A, F	13	372	23 (3, 2, 3, 2, and 3 were consecutive)	1019	1032
4A	Radial	w/o RAT	E, B	15	17		1047	1102
4B	Radial	w/ RAT	D, G	16	477	36 (7, 2, 2, 8, and 3 were consecutive)	1107	1123
5A	Star	w/o RAT	C, A	19	25		1144	1203

5B	Star	w/ RAT	F, E	17	501	14 (6 and 2 were consecutive)	1209	1226
6A	Cloverleaf	w/o RAT	G, B	23	28		1247	1310
6B	Cloverleaf	w/ RAT	D, C	19	590	43 (2, 9, 2, 2, 7, 2, 3, and 2 were consecutive)	1303	1322

Appendix I: Summary of each BEE scenario

Scenario #	Survey Technique	w/o or w/ RAT	Team	Duration (minutes)	# of points surveyed	# of points lost	Start time	End time
1A	Modified Lane	w/o RAT	D, A	37	37		0804	0841
1B	Modified Lane	w/ RAT	E, G	21	619	16 (4, 2, and 2 were consecutive)	0904	0925
2A	Modified Zigzag	w/o RAT	B, C	37	32		0951	1028
2B	Modified Zigzag	w/ RAT	F, A	12 (incomplete)	379	54 (2, 8, 3, 2, 2, 3, 4, 3, 2, and 2 were consecutive)	1104	1116
2B	Modified Zigzag	w/ RAT	F, A	19	969	0	1251	1310
3A	Bounce and Bypass	w/o RAT	E, C	15	14		1346	1401
3B	Bounce and Bypass	w/ RAT	B, G	10	500	0	1415	1425
4A	Radial	w/o RAT	E, D	24	33		1450	1514
4B	Radial	w/ RAT	E, D	11	591	0	1536	1547

5A	Star	w/o RAT	F, A	22	29		1616	1638
5B	Star	w/ RAT	F, A	8	410	0	1650	1658
6A	Cloverleaf	w/o RAT	B, C	41	36		1736	1817
6B	Cloverleaf	w/ RAT	B, C	14	701	37 (2, 2, 3, 4, 11, 6, 3, and 2 were consecutive)	1836	1850

# Appendix J: DA Form 1971-Rs

Scenario #1a

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC					23 Nov 09					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM-300				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	
1	A 07492 44074	0708	1.42		16	P 07492 44074	0724	5.78 mR/hr		
2	B 07492 44074	0709	2.47		17	Q 07491 44074	0725	6.55 mR/hr		
3	C 07491 44074	0710	4.62 mR/hr		18	R 0735 54321	0728	8.12 mR/hr		
4	D 07491 44074	0712	4.18		19	S	0729	6.61 mR/hr		
5	E 07490 44074	0713	4.34		20	T	0730	5.73 mR/hr		
6	F 07440 44074	0714	3.22 mR/hr		21	U	0731	4.41 mR/hr		
7	G 07490 44074	0715	3.04 mR/hr		22	V 07490 44074	0731	3.08 mR/hr		
8	H 07440 44074	0716	2.75 mR/hr		23	W 07490 44074	0733	2.95 mR/hr		
9	I 07490 44074	0717	5.0 mR/hr		24	X 07490 44074	0734	3.75 mR/hr		
10	J 07490 44074	0718	3.72 mR/hr		25	Y 07491 44074	0735	3.12 mR/hr		
11	K 07491 44074	0719	5.62 mR/hr		26	Z 07491 44074	0736	4.02 mR/hr		
12	L 07491 44074	0720	4.73 mR/hr		27	AA 07492 44074	0737	1.81 mR/hr		
13	M 07491 44074	0721	6.61 mR/hr		28	BB 07492 44074	0738	1.22 mR/hr		
14	N 07490 44074	0722	1.55 mR/hr		29					
15	O 07492 44074	0722	4.8 mR/hr		30					
REMARKS Time Start 0708 All measurements are in mR/hr Time Complete 0739 unless noted * DO NOT USE. For control party only										
CORRELATION FACTOR DATA										
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	
		INSIDE	OUTSIDE				INSIDE	OUTSIDE		

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

R-Uniform Grids

2 problems w/ GPS

Scenario 2A

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE						DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC						23 Nov 09					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE HDM 300					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	A 07492 44074	0826	3.20 MR/h		16	P 07492 44073	0843	3.90 MR/h			
2	B 07491 44074	0828	4.95 MR/h		17	A 07492 44073	0843	2.42 MR/h			
3	C 07491 44074	0829	6.36 MR/h		18	E 07491 44073	0844	10.2 MR/h			
4	D 07490 44074	0831	2.73 MR/h		19	S 07491 44073	0845	8.25 MR/h			
5	E 07490 44074	0832	4.36 MR/h		20	T 07490 44073	0846	7.53 MR/h			
6	F 07495 44073	0832	9.12 MR/h		21	V 07490 44073	0847	6.35 MR/h			
7	G 07491 44073	0833	10.9 MR/h		22	V 07491 44073	0848	7.57 MR/h			
8	H 07492 44073	0834	4.66 MR/h		23	W 07491 44073	0849	6.96 MR/h			
9	J 07492 44073	0835	7.22 MR/h		24	X 07492 44073	0850	4.97 MR/h			
10	J 07491 44073	0836	9.14 MR/h		25	Y O					
11	K 07491 44073	0837	6.73 MR/h		26	Z O					
12	L 07490 44073	0838	9.52 MR/h		27	AA O					
13	M 07490 44076	0839	6.85 MR/h		28	BB O					
14	N 07491 44073	0840	6.37 MR/h		29						
15	O 07491 44073	0842	6.41 MR/h		30						
REMARKS											
Start time - 0826											
Time Complete - 0850											
* DO NOT USE. For control party only											
CORRELATION FACTOR DATA											
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*		
		INSIDE	OUTSIDE				INSIDE	OUTSIDE			

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

Scenario 3A

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE						DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC						23 NOV 09					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM 300					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	A 0749344074	0953	1.49 mR/h		16	P					
2	B 0749344074	0954	6.47 mR/h		17	Q					
3	C 0749344073	0955	2.04 mR/h		18	R					
4	D 0749344073	0957	10.0 mR/h		19	S					
5	E 0749344073	0957	2.49 mR/h		20	T					
6	F 0749344073	0959	6.13 mR/h		21	U					
7	G 0749344073	1000	3.89 mR/h		22	V					
8	H 0749344073	1001	8.57 mR/h		23	W					
9	I	1003	4.8 mR/h		24	X					
10	J	1004	5.6 mR/h		25	Y					
11	K	1005	2.19 mR/h		26	Z					
12	L	1007	760 uR		27						
13	M	1009	1.69 mR/h		28						
14	N				29						
15	O				30						
REMARKS Start time-0953 Time Complete- * DO NOT USE. For control party only											
CORRELATION FACTOR DATA											
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*		
		INSIDE	OUTSIDE				INSIDE	OUTSIDE			

GPS stopped working →

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE



Scenario 4A

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE						DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC						23/100 09					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM-300					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	A 07492-44072	1048	3.59		16	P 07492-44072	1101	3.03			
2	B 07492-44072	1049	4.15		17	Q 07492-44072	1101	2.44			
3	C 07492-44072	1050	3.65		18	R MC					
4	D 07492-44072	1051	2.90		19	S					
5	E 07492-44072	1052	3.75		20	T					
6	F 07492-44072	1053	4.32		21						
7	G 07492-44072	1054	4.37		22						
8	H 07492-44072	1055	9.72		23						
9	I 07492-44072	1055	4.30		24						
10	J 07492-44072	1056	3.72		25						
11	K 07492-44072	1057	4.43		26						
12	L 07492-44072	1058	4.47		27						
13	M 07492-44072	1059	3.88		28						
14	N 07492-44072	1059	3.36		29						
15	O 07492-44072	1100	4.33		30						
REMARKS Time Start: 1047 Time Complete: 1102 * DO NOT USE. For control party only											
CORRELATION FACTOR DATA											
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*		
		INSIDE	OUTSIDE				INSIDE	OUTSIDE			

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

Scenario SA

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE	PAGE NO.	NO. OF PAGES		
For use of this form, see FM 3-3-1; the proponent agency is TRADOC					23 Nov 09	1	1		
MAP USED		TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE				
					ADM 360				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*
1	A 0749507 4407279	1144	3.95 m/r		16	A 0749549 4407274	1157	1.97 m/r	
2	B 0749509 4407258	1145	4.04 m/r		17	A 0749533 4407262	1157	1.33 m/r	
3	C 0749512 4407274	1146	4.21 m/r		18	A 0749523 4407297	1158	3.2 m/r	
4	D 0749519 4407266	1146	4.22 m/r		19	C 0749515 4407251	1159	2.3 m/r	
5	E 0749526 4407254	1147	3.9 m/r		20	F 0749505 4407241	1200	2.61 m/r	
6	F 0749528 4407244	1148	2.47 m/r		21	G 0749495 4407253	1200	2.67 m/r	
7	G 0749514 4407247	1149	2.79 m/r		22	H 0749497 4407251	1201	1.93 m/r	
8	H 0749500 4407255	1149	3.13 m/r		23	I 0749497 4407266	1201	4.95 m/r	
9	I 0749490 4407261	1150	1.63 m/r		24	J 0749503 4407279	1202	3.65 m/r	
10	J 0749481 4407269	1151	1.39 m/r		25	K 0749503 4407289	1203	3.90 m/r	
11	K 0749467 4407269	1153	1.44 m/r		26				
12	L 0749469 4407268	1154	2.66 m/r		27				
13	M 0749502 4407269	1154	2.08 m/r		28				
14	N 0749523 4407271	1155	6.80 m/r		29				
15	O 0749540 4407273	1156	1.94 m/r		30				
REMARKS all readings in mR/hr unless noted									
* DO NOT USE. For control party only									
CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

Time Start 1144  
Time End 1203

Scenario 6A

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE						DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC						23 NOV 09		1		1	
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM 300					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	A 0749405 4407315	1247	3.27 m/r		16	P 0749384 4407310	0100	6.79 m/r			
2	B 0749408 4407331	1248	3.32 m/r		17	Q 0749391 4407187	0101	6.90 m/r			
3	C 0749420 4407345	1249	4.06 m/r		18	R 0749406 4407193	0102	5.53 m/r			
4	D 0749405 4407344	1250	2.80 m/r		19	S 0749417 4407301	0103	7.51 m/r			
5	E 0749420 4407345	1251	1.90 m/r		20	T 0749416 4407220	0103	7.46 m/r			
6	F 0749385 4407324	1251	2.50 m/r		21	U 0749412 4407244	0104	9.69 m/r			
7	G 0749382 4407308	1252	4.01 m/r		22	V 0749448 4407244	0105	7.74 m/r			
8	H 0749366 4407297	1253	3.40 m/r		23	W 0749456 4407243	0106	8.19 m/r			
9	I 0749345 4407088	1254	2.50 m/r		24	X 0749464 4407249	0106	8.88 m/r			
10	J 0749350 4407284	1255	2.18 m/r		25	Y 0749464 4407266	0107	6.06 m/r			
11	K 0749330 4407271	1255	1.30 m/r		26	Z 0749406 4407276	0108	5.38 m/r			
12	L 0749332 4407258	1256	2.94 m/r		27	AA 0749453 4407281	0109	5.25 m/r			
13	M 0749348 4407266	1257	2.63 m/r		28	BB 0749441 4407289	0110	7.07 m/r			
14	N 0749379 4407270	1258	3.22 m/r		29						
15	O 0749381 4407246	1259	2.85 m/r		30						
REMARKS All readings in mR/hr											
* DO NOT USE. For control party only											
CORRELATION FACTOR DATA											
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*		
		INSIDE	OUTSIDE				INSIDE	OUTSIDE			

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

Time Start: 1247  
Time End: 0110



104

LANE

START TIME: \_\_\_\_\_  
END TIME: \_\_\_\_\_

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE <small>For use of this form, see FM 3-3-1; the proponent agency is TRADOC</small>					DATE 15 DEC 09		PAGE NO.		NO. OF PAGES	
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM300				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	
1	0749234 4407455	0826	1.91 MR16		16	0749078 4407446	0821	4.93		
2	0749224 4407407	0826	1.93		17	0749101 4407400	0821	5.20		
3	-	0826	4.67		18	0749102 4407447	0822	6.21		
4	0749175 4407466	0807	5.02		19	0749143 4407449	0823	5.57		
5	-	0808	4.81		20	0749144 4407448	0824	5.17		
6	0749173 4407465	0808	3.26		21	0749198 4407453	0825	1.80		
7	0749190 4407464	0813	5.59		22	0749220 4407453	0826	1.07		
8	0749132 4407462	0811	4.82		23	0749222 4407437	0827	5.20		
9	0749097 4407464	0813	2.74		24	0749199 4407436	0828	3.72		
10	0749057 4407462	0815	1.86		25	0749175 4407433	0828	4.83		
11	0749029 4407457	0816	4.35		26	0749142 4407432	0829	4.69		
12	0749007 4407446	0817	3.94		27	0749098 4407424	0830	5.18		
13	0749008 4407444	0818	4.58		28	0749059 4407427	0831	5.85		
14	0749030 4407443	0818	3.96		29	0749006 4407414	0832	2.83		
15	0749055 4407413	0819	6.18		30	0749007 4407416	0833	2.46		

REMARKS

\* DO NOT USE. For control party only

CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC										
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	
1	0749055 4487414	0834	2.75		16					
2	0749059 4487417	0836	4.19		17					
3	0749195 4487418	0837	5.24		18					
4	0749174 4487418	0838	2.91		19					
5	0749128 4487420	0838	3.44		20					
6	0749197 4487419	0840	1.59		21					
7	0749222 4487422	0841			22					
8	Stop	0841			23					
9					24					
10					25					
11					26					
12					27					
13					28					
14					29					
15					30					
REMARKS										
* DO NOT USE. For control party only										
CORRELATION FACTOR DATA										
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	
		INSIDE	OUTSIDE				INSIDE	OUTSIDE		

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

2A ZIGZAG

START TIME: \_\_\_\_\_  
END TIME: \_\_\_\_\_

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE For use of this form, see FM 3-3-1; the proponent agency is TRADOC					DATE 15 DEC 89		PAGE NO.		NO. OF PAGES		
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)						
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE ADM300					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	074433 4407405	0961	2.68		16	0744214 4407370	1007	3.70			
2	0744230 4407409	0952	1.97		17	0744140 4407366	1009	6.14			
3	0744220 4407414	0954	2.25		18	0744152 4407370	1010	3.52			
4	0744198 4407403	0955	1.76		19	0744055 4407363	1012	9.46			
5	0744192 4407403	0955	7.86		20	0744054 4407351	1013	6.40			
6	0744170 4407400	0956	8.08		21	0744104 4407371	1013	7.67			
7	0744151 4407413	0956	2.47		22	0744151 4407359	1015	1.12			
8	0744053 4407400	0958	4.53		23	0744158 4407345	1016	77.00 <small>0.0000</small>			
9	0744083 4407383	0958	3.81		24	0744126 4407362	1017	4.72			
10	0744053 4407382	1000	6.93		25	0744127 4407349	1017	4.52			
11	0744080 4407382	1001	7.00		26	0744143 4407350	1019	5.13			
12	0744158 4407384	1002	4.34		27	0744151 4407323	1020	4.28			
13	0744187 4407353	1003	1.46		28	0744083 4407345	1022	3.49			
14	0744221 4407353	1005	1.93		29	0744084 4407317	1022	5.43			
15	0744234 4407375	1006	6.05		30	0744151 4407329	1024	2.70			

REMARKS

\* DO NOT USE. For control party only

STOP time 1028

CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	
0744141 4407321	1026	2	2.78						
0744127 4407321	1027		2.15						

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE



3A BOUNCE + BK PASS

START TIME: \_\_\_\_\_  
END TIME: \_\_\_\_\_

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE		PAGE NO.		NO. OF PAGES		
For use of this form, see FM 3-3-1; the proponent agency is TRADOC					15 DEC 49						
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)						
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE					
						AOM344					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	074937 4407403	1346	1.75		16						
2	074938 4407404	1346	4.54		17						
3	074939 4407405	1348	1.33		18						
4	074940 4407406	1349	5.44		19						
5	074941 4407407	1350	10.1		20						
6	074942 4407408	1351	2.44		21						
7	074943 4407409	1352	6.24		22						
8	074944 4407410	1353	5.71		23						
9	074945 4407411	1354	3.26		24						
10	074946 4407412	1355	4.45		25						
11	074947 4407413	1356	1.22		26						
12	074948 4407414	1357	4.75		27						
13	074949 4407415	1359	1.69		28						
14	074950 4407416	1400	5.13		29						
15		1401	STOP TIME		30						

REMARKS

\* DO NOT USE. For control party only

CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE

4A RADIAL

START TIME: 1450

END TIME: 1514

RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE		PAGE NO.		NO. OF PAGES		
For use of this form, see FM 3-3-1; the proponent agency is TRADOC					15 DEC 69						
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)						
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE AD1734					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	0749255 4407300	1450	6.33 mld		16	0749255 4407229	1500	4.43			
2	0749255 4407287	1451	4.88		17	0749241 4407235	1501	5.05			
3	0749255 4407247	1452	6.22		18	0749250 4407240	1501	5.33			
4	0749250 4407251	1452	4.10		19	0749257 4407229	1502	7.18			
5	0749242 4407237	1453	3.74		20	0749255 4407210	1504	7.24			
6	0749231 4407208	1454	3.44		21	0749257 4407208	1504	4.90			
7	0749240 4407201	1454	4.20		22	0749281 4407201	1505	3.77			
8	0749293 4407249	1455	4.43		23	0749268 4407250	1506	4.24			
9	0749241 4407240	1456	3.73		24	0749274 4407249	1506	4.92			
10	0749222 4407240	1456	3.81		25	0749268 4407250	1507	5.12			
11	0749237 4407240	1457	5.01		26	0749255 4407245	1508	6.29			
12	0749244 4407248	1458	4.87		27	0749221 4407210	1509	4.75			
13	0749253 4407247	1458	4.82		28	0749269 4407240	1509	4.89			
14	0749245 4407244	1459	3.66		29	0749250 4407240	1510	5.30			
15	0749232 4407221	1459	3.88		30	0749223 4407210	1510	7.09			

REMARKS

\* DO NOT USE. For control party only

CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

DA FORM 1971-R, SEP 94

EDITION OF SEP 86 IS OBSOLETE



RADIOLOGICAL DATA SHEET- MONITORING OR POINT TECHNIQUE					DATE		PAGE NO.		NO. OF PAGES	
For use of this form, see FM 3-3-1; the proponent agency is TRADOC										
SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	
1	0749257 4407247	1512	4.361		16					
2	0749263 4407261	1513	3.70		17					
3	0749280 4407273	1513	3.25		18					
4					19					
5					20					
6					21					
7					22					
8					23					
9					24					
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REMARKS										
* DO NOT USE. For control party only										
CORRELATION FACTOR DATA										
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	
		INSIDE	OUTSIDE				INSIDE	OUTSIDE		

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END TIME: \_\_\_\_\_

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SURVEY PARTY OR MONITORING UNIT DESIGNATION						MONITOR (Print name)					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE <b>AD730P</b>					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	0749507 4407208	1616	5.33		16	0749492 4407271	1628	11.5			
2	0749512 4407207	1617	8.36		17	0749539 4407273	1628	5.35			
3	0749513 4407292	1618	9.15		18	0749528 4407273	1629	5.12			
4	0749515 4407287	1618	8.04		19	0749544 4407275	1630	7.44			
5	0749520 4407274	1619	9.20		20	0749552 4407275	1631	9.31			
6	0749521 4407271	1620	8.69		21	0749547 4407270	1631	10.3			
7	0749523 4407264	1621	9.26		22	0749540 4407265	1632	8.20			
8	0749527 4407253	1621	6.19		23	0749527 4407258	1633	6.87			
9	0749531 4407296	1622	9.84		24	0749518 4407252	1633	6.84			
10	0749527 4407244	1623	10.4		25	0749503 4407261	1634	5.18			
11	0749516 4407247	1624	9.75		26	0749494 4407230	1635	6.32			
12	0749503 4407251	1624	3.16		27	0749473 4407241	1635	6.67			
13	0749493 4407255	1625	2.12		28	0749486 4407255	1636	5.34			
14	0749483 4407259	1626	4.73		29	0749479 4407266	1637	4.81			
15	0749470 4407265	1627	6.59		30	07495	1638	Stop			

REMARKS

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CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

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						ADM347					
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*		
1	0749405 44071304	17:31	20.09		16	0749330 4407130	1741	1.65			
2	0749405 4407130	1737	4.43		17	0749403 4407130	1754	1.98			
3	0749400 4407134	1738	6.91		18	0749404 4407130	1755	2.33			
4	0749407 4407133	1740	6.15		19	0749364 4407130	1757	2.75			
5	0749412 4407133	1741	3.07		20	0749403 4407130	1759	9.11			
6	0749444 4407134	1742	6.98		21	0749307 4407130	1800	3.18			
7	0749409 4407134	1743	13.35		22	0749387 4407130	1801	5.41			
8	0749438 4407134	1743	4.51		23	0749403 4407130	1802	2.75			
9	0749438 4407134	1740	5.14		24	0749403 4407130	1803	2.63			
10	0749438 4407134	1747	6.12		25	0749403 4407130	1804	3.15			
11	0749438 4407134	1748	3.87		26	0749403 4407130	1805	3.77			
12	0749438 4407134	1748	2.64		27	0749403 4407130	1806	3.14			
13	0749438 4407134	1751	2.95		28	0749403 4407130	1807	5.64			
14	0749438 4407134	1751	1.25		29	0749403 4407130	1810	7.72			
15	0749438 4407134	1753	2.78		30	0749403 4407130	1811	8.64			

REMARKS

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CORRELATION FACTOR DATA									
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*
		INSIDE	OUTSIDE				INSIDE	OUTSIDE	

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SURVEY PARTY OR MONITORING UNIT DESIGNATION					MONITOR (Print name)					
MAP USED			TYPE OF VEHICLE OR OTHER SHIELDING			INSTRUMENT TYPE				
READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	READING NO.	LOCATION	TIME	DOSE RATE (cGyph)	DO NOT USE*	
1	07019464 4467246	1812	5.77		16					
2	07019464 4467246	1812	6.02		17					
3	07019464 4467246	1814	9.12		18					
4	07019464 4467246	1814	4.34		19					
5	07019464 4467246	1816	4.48		20					
6	07019464 4467246	1817	2724cm		21					
7		1817	5024cm		22					
8					23					
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REMARKS										
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CORRELATION FACTOR DATA										
LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	LOCATION	READING NO.	DOSE RATE (cGyph)		CF*	
		INSIDE	OUTSIDE				INSIDE	OUTSIDE		

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## Appendix K: Summary calculations

**Table K1: % decrease in time using RAT**

Scenario	% increase or decrease in time
WMD-CST Lane	Decrease 35%
BEE Lane	Decrease 43%
WMD-CST Zigzag	Increase 25%
BEE Zigzag	Decrease 49%
WMD-CST Bounce and Bypass	Decrease 19%
BEE Bounce and Bypass	Decrease 33%
WMD-CST Radial	Increase 7%
BEE Radial	Decrease 54%
WMD-CST Star	Decrease 11%
BEE Star	Decrease 64%
WMD-CST Cloverleaf	Decrease 17%
BEE Cloverleaf	Decrease 66%
Total decrease in time	359%
Total decrease in time (359%)/ number of iterations (12)	<b>29.91667%</b>

**Table K2: % increase in number of points collected using RAT**

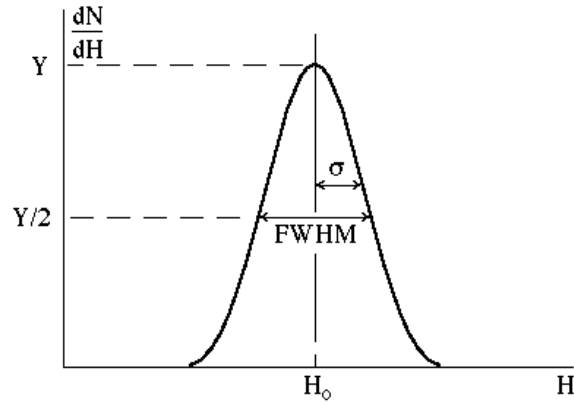
<b>Scenario</b>	<b>Number of points collected without RAT</b>	<b>Number of points collected with RAT</b>	<b>x times increase using RAT</b>
WMD-CST Lane	28	614	21.92857143
BEE Lane	37	619	16.72972973
WMD-CST Zigzag	24	888	37
BEE Zigzag	32	969	30.28125
WMD-CST Bounce and Bypass	13	372	28.61538462
BEE Bounce and Bypass	14	500	35.71428571
WMD-CST Radial	17	477	28.05882353
BEE Radial	33	591	17.90909091
WMD-CST Star	25	501	20.04
BEE Star	29	410	14.13793103
WMD-CST Cloverleaf	28	590	21.07142857
BEE Cloverleaf	36	701	19.47222222
Total times increase using RAT (sum of last column)			290.9587178
Average total times increase using RAT (sum of last column/12)			<b>24.24656</b>

## Appendix L: SAM 940

The SAM 940 is one of the most user friendly pieces of equipment in the first responder community. Navigating the screens is very intuitive. A first time user could be trained on the proper operation of the equipment in under one hour. Quarterly one hour refresher training would be sufficient to maintain proficiency. Furthermore, 15 minutes during mission rehearsals is adequate to conduct refresher training on a member who hasn't operated the equipment in months.

Two characteristics of the SAM 940-2-L Revealer contribute most significantly to its excellent performance. They include the detector's  $\text{LaBr}_3$  (lanthanum bromide) crystal and its use of a Quadratic Compression Conversion (QCC) algorithm.

Currently, Berkeley Nucleonics Corporation's® (BNC) SAM 940-2-L Revealer represents its best performing and most expensive detector. The SAM 940-2-L Revealer uses a  $1.5 \times 1.5$   $\text{LaBr}_3$  crystal and provides a 2.8% resolution whereas the other four SAM 940 Defender models use a NaI (sodium iodide) crystal and provide a 7% resolution (Model 940 RIID SAM Specifications, 2009). For 662 keV photons, Flamanc and Rozsa experimented with the  $\text{LaBr}_3$  crystal and produced results with a 2.6% full width at half maximum (FWHM) (Flamanc and Rozsa, 2008). The following figure displays FWHM on a Gaussian distribution.



**Figure L1: FWHM on a Gaussian distribution (Kowash, 2009a)**

FWHM serves as a very important characteristic for a detector. The narrower the FWHM, the better the resolution the detector will produce. The following equation explains the relationship between the values displayed on the above figure.

**Equation 1: Resolution equation (Knoll, 2000)**

$$\text{Resolution (R)} = \text{FWHM}/H_0 = 2.35\sigma/H_0$$

In addition to the great energy resolution, the crystal provides the following properties: a very high scintillation light yield of over 65,000 photons/MeV, fast emission with a decay time of 16 ns, and a good density of  $5.1 \text{ g/cm}^3$  (Flamanc and Rozsa, 2009). Furthermore, the quality of energy resolution results from the nearly proportional relationship between light output and photon energy (Flamanc and Rozsa, 2009). Various factors contribute to the overall FWHM. We may explore the contribution of a single component to the overall FWHM through the following equation:



**Equation 2: FWHM<sub>overall</sub> equation (Knoll, 2000)**

$$(\text{FWHM}_{\text{overall}})^2 = (\text{FWHM}_{\text{statistical}})^2 + (\text{FWHM}_{\text{noise}})^2 + (\text{FWHM}_{\text{drift}})^2 + \dots$$

From this equation, we see the importance of decreasing the electronic noise. Knoll defines detector bias as the external high voltage required for a detector's proper operation (Knoll, 2000). As bias rises, the leakage current increases causing noise (Flamanc and Rozsa, 2008). Therefore, a detector requires both a low resolution and a low bias.

As previously mentioned, the detector's LaBr<sub>3</sub> crystal and its use of a QCC algorithm contribute to its great performance. The SAM 940 contains many advantages over other detectors because of its QCC algorithm. First, the SAM 940 uses the QCC's transform algorithm similar to how x-ray imaging uses fast Fourier transforms in order to enhance statistics ("Advantages of Quadratic Compression Conversion patented technology of the SAM 940," 2009). This step by step process will ultimately produce more accurate statistical results for the detector.

Second, QCC optimizes the energy peaks at all energy levels and places them into one of 11 distinguishable channels by taking the square root of the energy ("Advantages of Quadratic Compression Conversion patented technology of the SAM 940," 2009).

Third, the SAM 940 takes data every one second creating such a high level of sensitivity that it successfully detects at levels 20 times below background every second ("Advantages of Quadratic Compression Conversion patented technology of the SAM

940,” 2009). It compares the data from one second to the data from the previous second thereby creating a 97% confidence level in a relatively short period of time (“Advantages of Quadratic Compression Conversion patented technology of the SAM 940,” 2009). The detector subtracts background for each one second update; creating the opportunity to detect low energy peaks in high energy background environments and in circumstances where the unknown source is located a larger distance away, compounding the effects of the Inverse Square Law (“Advantages of Quadratic Compression Conversion patented technology of the SAM 940,” 2009). This also applies when searching for low energy isotopes like Americium-241 which may become difficult with the presence of high energy isotopes like Cesium-137 or Cobalt-60 (Model 940 RIID SAM Specifications, 2009). In each one second capture, the SAM 940 subtracts Compton scattering and bremsstrahlung, caused by backscatter from x-rays, in order to better detect some isotopes (Model 940 RIID SAM Specifications, 2009). Compton scattering represents the most dominant interaction mechanism for typical radioisotope source gamma energies, in the 1-5 MeV range (Knoll, 2000) (Kowash, 2009b). This interaction occurs between the incident gamma-ray photon and an absorbing material’s electron (Knoll, 2000). “When fast electrons interact in matter, part of their energy is converted into electromagnetic radiation in the form of bremsstrahlung.” (Knoll, 2000) At levels above a few MeV, the fraction of secondary electrons losing energy by bremsstrahlung photons increases significantly, making it the dominant process (Knoll, 2000).

Fourth, QCC conquers the challenges associated with branching. “Branching possibilities exist when a fission product decays to more than one isomeric state with

different half-lives.” (Bridgman, 2001) QCC enables the detector to identify the low branching intensities of Uranium and Plutonium (“Advantages of Quadratic Compression Conversion patented technology of the SAM 940,” 2009).

Finally, the SAM 940 use Potassium-40 to stabilize the detector (Model 940 RIID SAM Specifications, 2009). Therefore, by using Potassium-40 instead of Cesium-137, the stabilizer prevents false positives or other abnormalities in the detection of Cesium-137 (Model 940 RIID SAM Specifications, 2009).

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<b>14. ABSTRACT</b> <p>First responders assess a Nuclear/Radiological (NUCRAD) event in a timely and accurate manner by creating a site characterization that reflects the location of various levels of contamination based on their instruments' readings. The survey team experiences difficulty in accurately recording this critical data due to the challenge of operating multiple devices and communicating the devices' readings to other survey members. First responders produce a representation of the contamination or activity on a map that contain rings outlining the levels of activity and/or single locations of a single activity. Recently, several agencies began creating software programs that record a first responder's instrument readings, time, and the global positioning system (GPS) location plotting the information in real-time. The Environmental Protection Agency (EPA) Region 5 developed the Rapid Assessment Tool (RAT). This research evaluates the effectiveness of RAT by comparing the timeliness and accuracy of the site characterization created by multiple survey teams (one team not using RAT and another team using RAT).</p> <p>All of the Bioenvironmental Engineer (BEE) Survey Teams using RAT decreased their survey times for all scenarios. The Weapons of Mass Destruction – Civil Support Team (WMD-CST) survey teams using RAT decreased their survey times during the lane, bounce and bypass, star, and cloverleaf scenarios. However, survey times increased for the zigzag and radial scenarios.</p>					
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